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Report of the tests of metals and other materials for industrial ...

United States. Army. Ordnance Dept,
Watertown Arsenal (Mass.)

REPORT

OF THE

TESTS OF METALS

AND

OTHER MATERIALS

MADE WITH THE

UNITED STATES TESTING MACHINE AT WATERTOWN
ARSENAL, MASSACHUSETTS, DURING THE
FISCAL YEAR ENDED JUNE 30

1914

WASHINGTON
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War Department.

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LETTER OF TRANSMITTAL.

War Department,
Washington, August 26, 1914.

The Speaker of the House of Representatives.

Sir: I have the honor to transmit herewith a letter from the Acting Chief of Ordnance, United States Army, of this date, submitting, for transmission to Congress, as required by law, the report of the commanding officer of Watertown Arsenal of "tests of iron and steel and other materials for industrial purposes" made at that arsenal during the fiscal year ended June 30, 1914.

Very respectfully,

Lindley M. Garrison,
Secretary of War.

LETTER OF SUBMITTAL.

War Department,
Office of the Chief of Ordnance,
Washington, August 26, 1914.

From: The Ordnance Office.
To: The Secretary of War.
Subject: Annual report, tests of iron, steel, etc., 1914.

I submit herewith, for transmission to Congress, as required by law, the report of the commanding officer of Watertown Arsenal of "tests of iron and steel and other materials for industrial purposes" made at that arsenal during the fiscal year ended June 30, 1914.

E. B. Babbitt,
Colonel, Ordnance Department,
Acting Chief of Ordnance.

Watertown Arsenal,
Watertown, Mass., August 17, 1914.

From: Commanding Officer, Watertown Arsenal.
To: Chief of Ordnance, United States Army, Washington, D. C.
Subject: Annual report of "tests of metals, etc.," for year ending June 30, 1914.

1. The annual report of tests of iron, steel, and other materials made at this arsenal during the fiscal year ending June 30, 1914, is submitted herewith.

2. The total number of specimens tested during the year was 3,192, classified as follows:

For Ordnance Department	2,552
Other Government departments	71
Private tests	569
Total	3,192

The receipts and expenditures were as follows:

Amount allotted for testing machine and testing work	$14,950.00
Received from private tests	839.18
Total received	15,789.18
Amount expended for services and labor	11,428.51
Amount expended for light, power, tools, implements, and material for test	4,360.67
Total expended	15,789.18

3. The equipment of the laboratory has been increased by the purchase of the following apparatus:

One Holborn-Kurlbaum optical pyrometer.
One Charpy impact machine.
One Weston laboratory standard millivoltmeter.
One Weston laboratory standard milliammeter with shunt.

4. The test to determine the relative wearing qualities of bronzes, referred to in the last report, has been continued during the year, and a report of the results is contained herein.

5. The machine for testing bronze gears has been redesigned and the test of these gears is now being continued.

6. Some interesting experiments were made in connection with the question of strength of shrapnel case material, and a number of tests have been made with the Charpy impact machine, principally for the purpose of calibrating it and determining its relative usefulness to the laboratory.

7. Numerous physical tests and metallographic examinations have been made in connection with experiments pertaining to the heat treatment of steels, and considerable time and study have been devoted to the subject of erosion of guns by Dr. Henry Fay.

C. B. Wheeler,
Lieutenant Colonel, Ordnance Department.

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REPORT

OF THE

TESTS OF METALS

AND

OTHER MATERIALS

MADE WITH THE

UNITED STATES TESTING MACHINE AT WATERTOWN
ARSENAL, MASSACHUSETTS, DURING THE
FISCAL YEAR ENDED JUNE 30, 1914.

SHRAPNEL CASES.

HYDROSTATIC TESTS OF 6-INCH, 3-INCH, AND 2.95-INCH SHRAPNEL CASES.

In order to determine the effect of streaks in shrapnel cases made from bar stock, the cases were subjected to hydraulic pressure in the testing machine until fracture occurred. The fixture used is shown in the sketch, page No. 13.

All cases were bored out until the inside diameter was uniform, thus making the thickness of wall constant and about 0.17 inch thick.

Measurements were taken on the external diameters until a dangerous pressure was reached, after which cases were covered and load continued until fracture occurred. All cases were rough polished and etched with iodine to develop the streaks. Photographs were taken both before and after testing.

6-INCH CASES.

Case A showed a line of fine streaks after etching. The case burst along these streaks and the interior of fracture also showed a number of bright slag streaks which did not appear on the surface. The metal appeared to be very brittle, fracture occurring in the peculiar manner shown in photograph.

Case B developed no streaks on etching. Failure occurred at a spot which appeared to be a defect due to rolling.

Case C was apparently free from streaks. This case was turned down on the outside according to the original program. An examination of the photographs of the other cases shows that the slag streaks are found all through the metal and not only on the surface. In 3-inch case H, slag streaks were found in the center of the base.

Case D showed numerous short streaks on etching. This was the worst of the four 6-inch cases tested, and also had the lowest strength. The fracture contained a number of bright slag streaks which were not apparent on the surface.

2.95-INCH CASES.

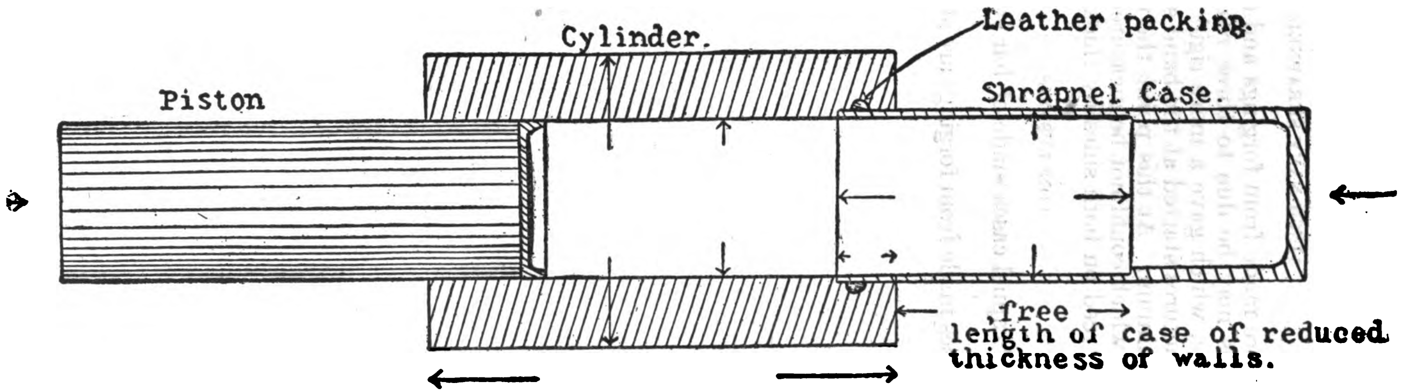
The streaks in case L were more pronounced than in K and the strength was lower. In both cases the fracture did not take place on a surface streak, but fracture showed larger and longer ones under the surface.

3-INCH CASES.

Cases A, B, C, and D were made from forgings. A crack was found in the wall of A, which rendered the hydraulic test impossible. The other three were free from surface streaks and when fractured the metal appeared tough, with no internal streaks apparent. The fiber stress ran from 153,000 to 163,000 pounds per square inch.

Cases G, H, I, and J were made from bar stock. All showed streaks except G. Case H was very bad, lines running the entire

TESTING ATTACHMENT.



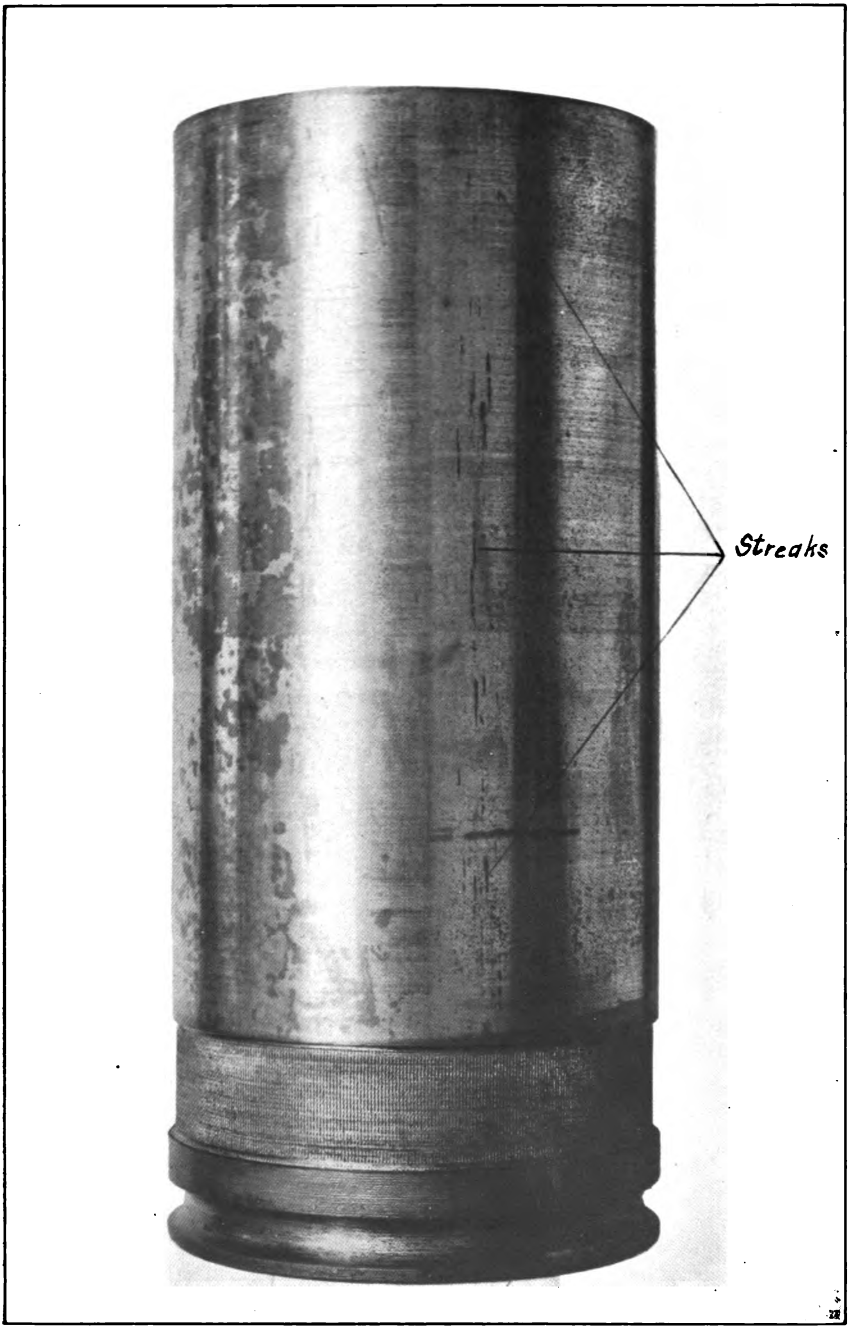
length of body. Fracture occurred along these lines. (See photograph.) This case had the greatest number of streaks and gave the lowest fiber stress of the four.

3-INCH NAVY SHRAPNEL.

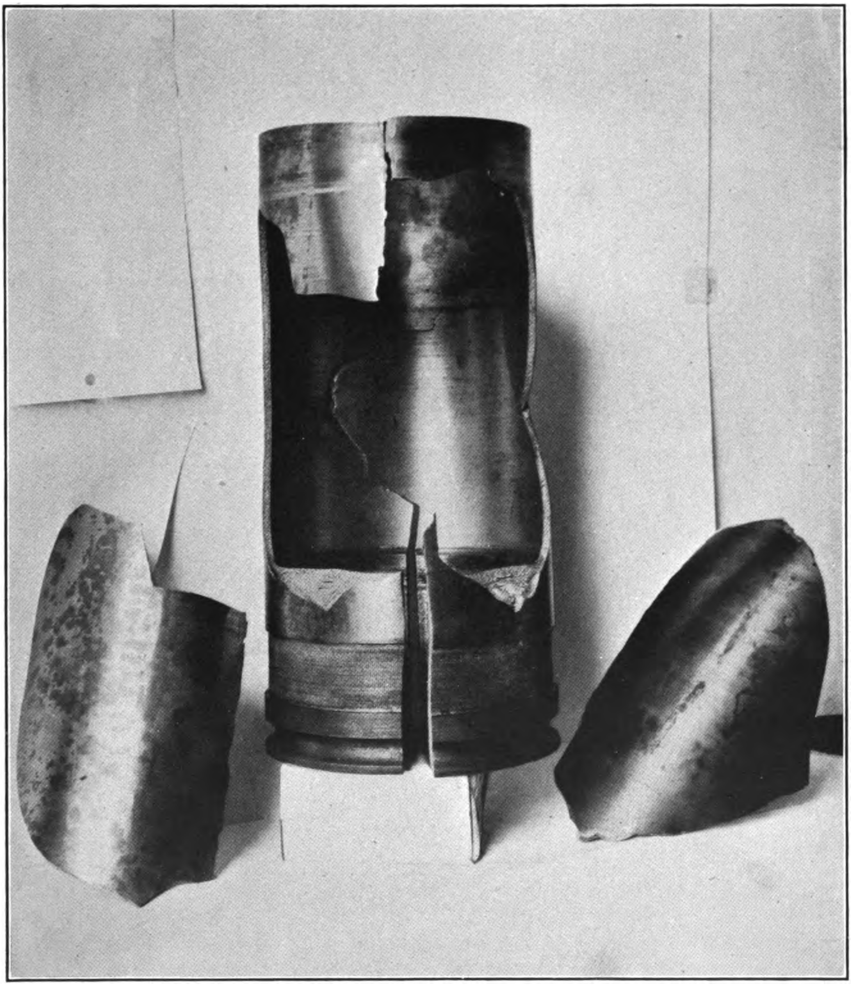
These cases were made from forgings and show an unusually high fiber stress. This may be due to three reasons. First. The short length of the case, which gave a more rigid cylinder. Second. The fact that both fractures started at the band seat where the thickness of wall was a minimum. At this point the rotating band exerted a reinforcing effect which could not be measured. Third. The reduced section was reinforced on both sides by thicker metal.

CONCLUSIONS.

1. Streaks in shrapnel cases made of bar stock are an indication of weakness.
2. Shrapnel cases made from forgings are stronger than those made from bar stock.



6-INCH SHRAPNEL CASE A MADE FROM BAR STOCK. P. O. 128 F. A. POLISHED AND ETCHED WITH IODINE. DARK LINES IN CENTER OF CASE ARE STREAKS.



6-INCH SHRAPNEL CASE A AFTER FRACTURE. CASE FAILED ALONG STREAKS. INTERIOR OF FRACTURE SHOWS BRIGHT STREAKS. BASE OF CASE SPLIT ENTIRELY ACROSS.

HYDROSTATIC TESTS OF 6-INCH, 2.95-INCH, AND 3-INCH SHRAPNEL CASES.

Marks on case, A 128.

6-inch shrapnel case made at Frankford Arsenal from bar stock.

Outside diameter of case, 5.90 inches.

Inside diameter of case, 5.56 inches.

Bored to a length of 9.20 inches.

Depth inside, 12.40 inches.

Length over all, outside, 13.22 inches.

Length from top to top of band groove, 10.60 inches.

Diameter of piston, 5 inches.

Sectional area, 19.63 square inches.

Case entered testing cylinder 1½ inches, leaving 7.70 inches length of reduced thickness of walls exposed to the interior pressures of the test.

The case contained two longitudinal streaks.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	....	0	5.90	
20,000	1,019	16,650	5.92	
40,000	2,038	33,400	5.925	
60,000	3,057	50,100	5.93	
80,000	4,076	66,800	5.935	
100,000	5,095	83,400	5.94	
120,000	6,110	100,200	5.95	
140,000	7,130	116,500	5.95	
150,000	7,645	125,000	5.955	
159,900	8,145	133,100	....	Ultimate strength.

Fractured at one of the longitudinal streaks.

Marks on case, B 2307.

6-inch shrapnel case made at Frankford Arsenal from bar stock.

Outside diameter of case, 5.90 inches.

Inside diameter of case, 5.56 inches.

Bored to a length of 9.20 inches.

Depth inside, 12.45 inches.

Length over all outside, 13.25 inches.

Length from top to top edge of band groove, 10.60 inches.

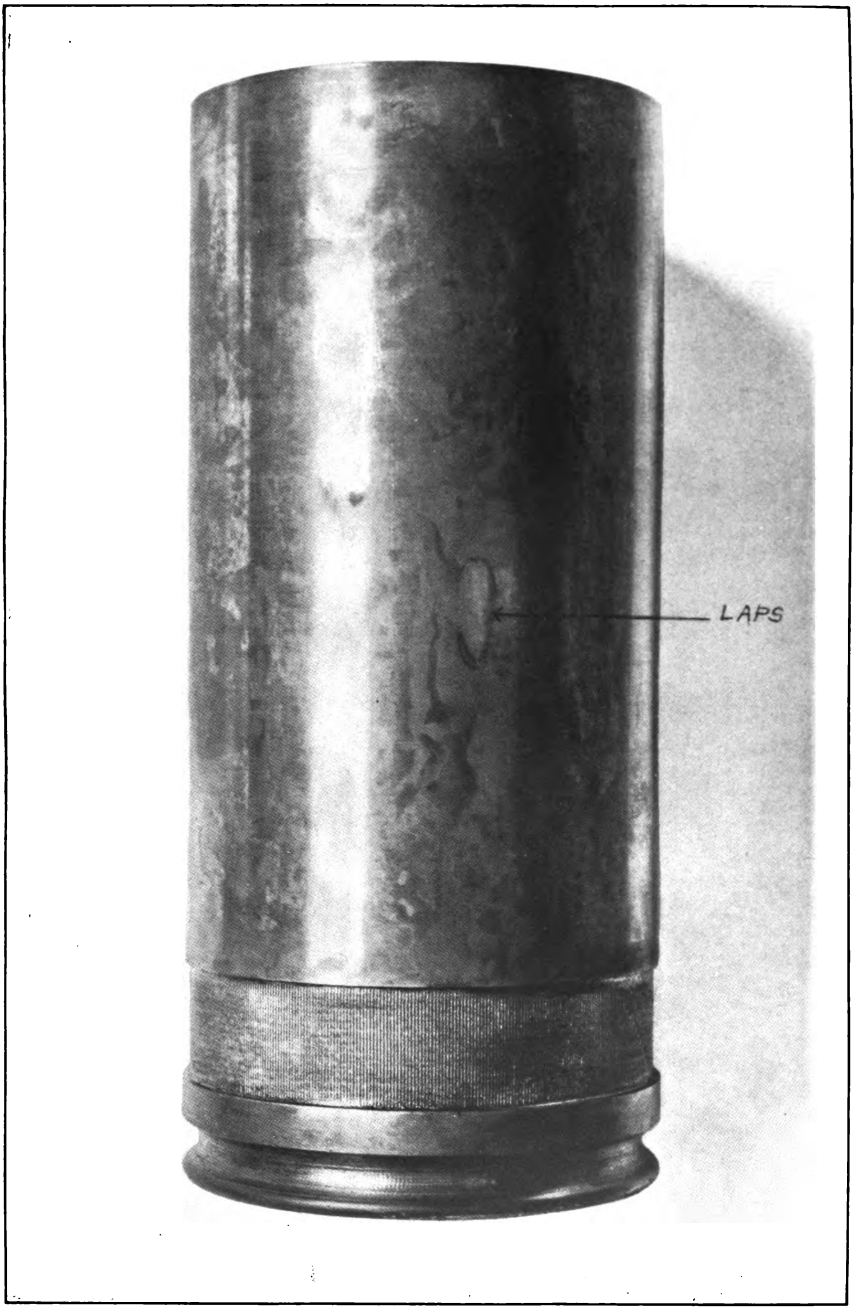
Case entered testing cylinder 1½ inches, leaving 7.70 inches length of reduced thickness of walls exposed to the interior pressures of the test.

Diameter of piston, 5 inches.

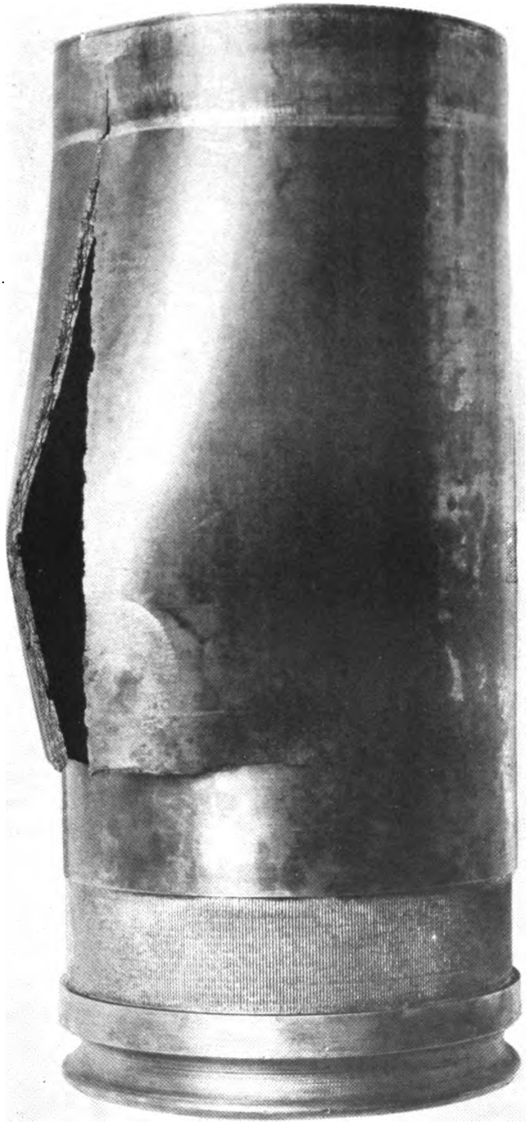
Sectional area, 19.63 square inches.

Case had no streaks.

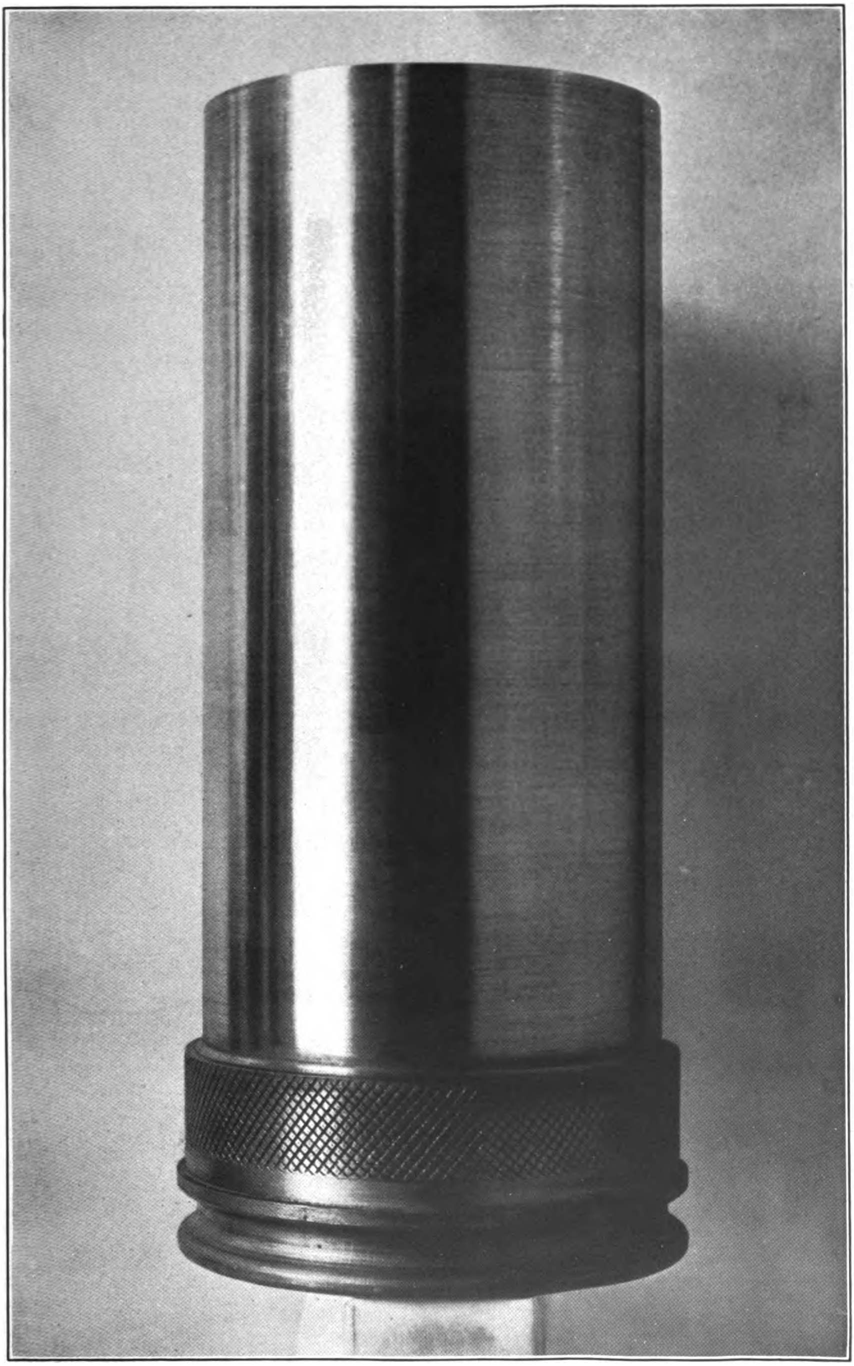
Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	....	0	5.90	
20,000	1,019	16,700	5.92	
40,000	2,038	33,400	5.925	
60,000	3,057	50,100	5.925	
80,000	4,076	66,800	5.93	
100,000	5,095	83,400	5.935	
120,000	6,110	100,200	5.94	
140,000	7,130	116,500	5.945	
150,000	7,645	125,000	5.95	
179,500	9,145	149,700	....	Ultimate strength.



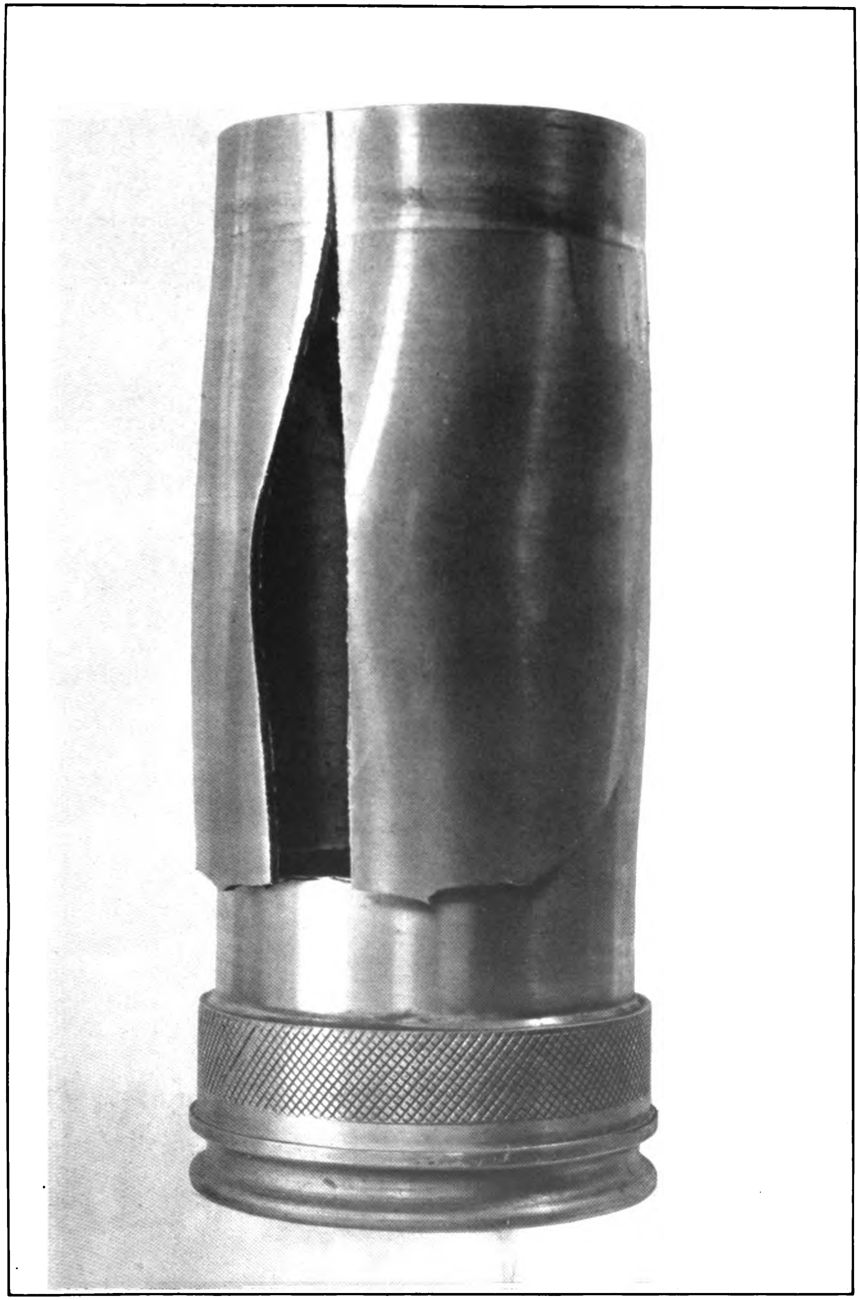
6-INCH SHRAPNEL CASE B MADE FROM BAR STOCK. F. A. P. O. 2307. POLISHED AND ETCHED WITH IODINE. NO STREAKS VISIBLE. A FEW SLIGHT LAPS OR COLD SHUTS IN ONE SPOT, SHOWN SURROUNDED BY PENCIL WORK IN PICTURE. FRACTURE STARTED AT THIS POINT.



6-INCH SHRAPNEL CASE B AFTER FRACTURE. FRACTURE SHOWS NO EXTERNAL OR INTERNAL STREAKS.



6-INCH SHRAPNEL CASE C. LOT 3-5352-13. FROM LOT THAT FAILED IN BALLISTIC TEST. OUTSIDE DIAMETER TURNED DOWN. POLISHED AND ETCHED WITH IODINE. NO STREAKS VISIBLE.



6-INCH SHRAPNEL CASE C AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS.

Marks on case, C Lot 3, 5352–13.

6-inch shrapnel case. Belongs to lot 3 which failed in ballistic test.

Exterior diameter of case turned to 5.32 inches.

Interior diameter of case bored to 4.98 inches for a length of 9¼ inches.

Case entered testing cylinder 1½ inches, leaving 7¾ inches length of reduced thickness of walls exposed to the interior pressures of the test.

Diameter of piston, 5 inches.

Sectional area, 19.63 square inches.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
50,000	2,547	37,450	5.34	
66,000	3,360	49,500	5.34	
115,000	5,860	86,400	5.35	
169,000	8,610	126,800	....	Elastic limit.
179,600	9,150	134,700	....	Ultimate strength.

Marks on case, D Lot 3, 5352–13.

6-inch shrapnel case, lot 3, that failed on retest.

Exterior diameter of case, 5.90 inches.

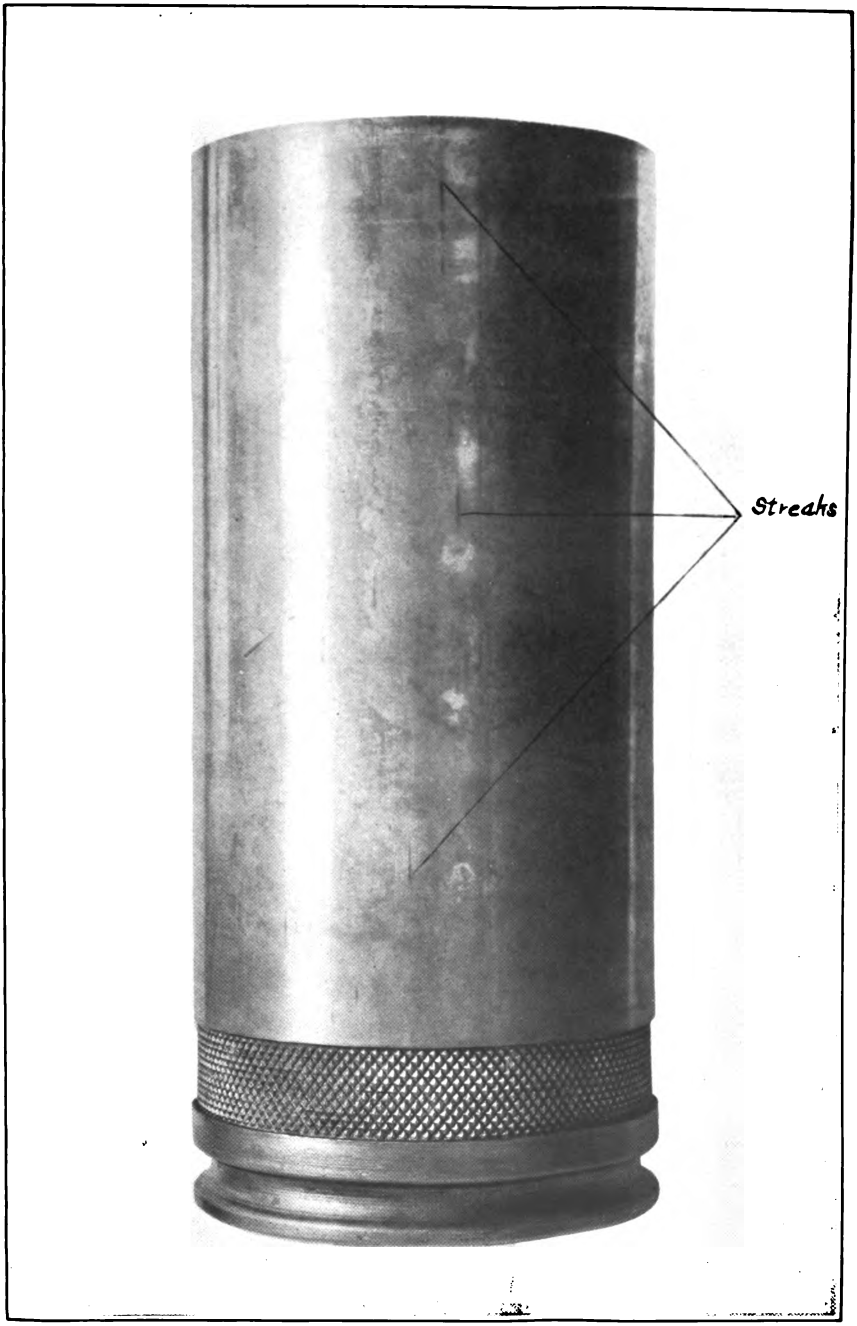
Interior diameter of case, 5.56 inches.

Case entered testing cylinder 1½ inches, leaving 7.70 inches length of reduced thickness of walls exposed to the interior pressures of the test.

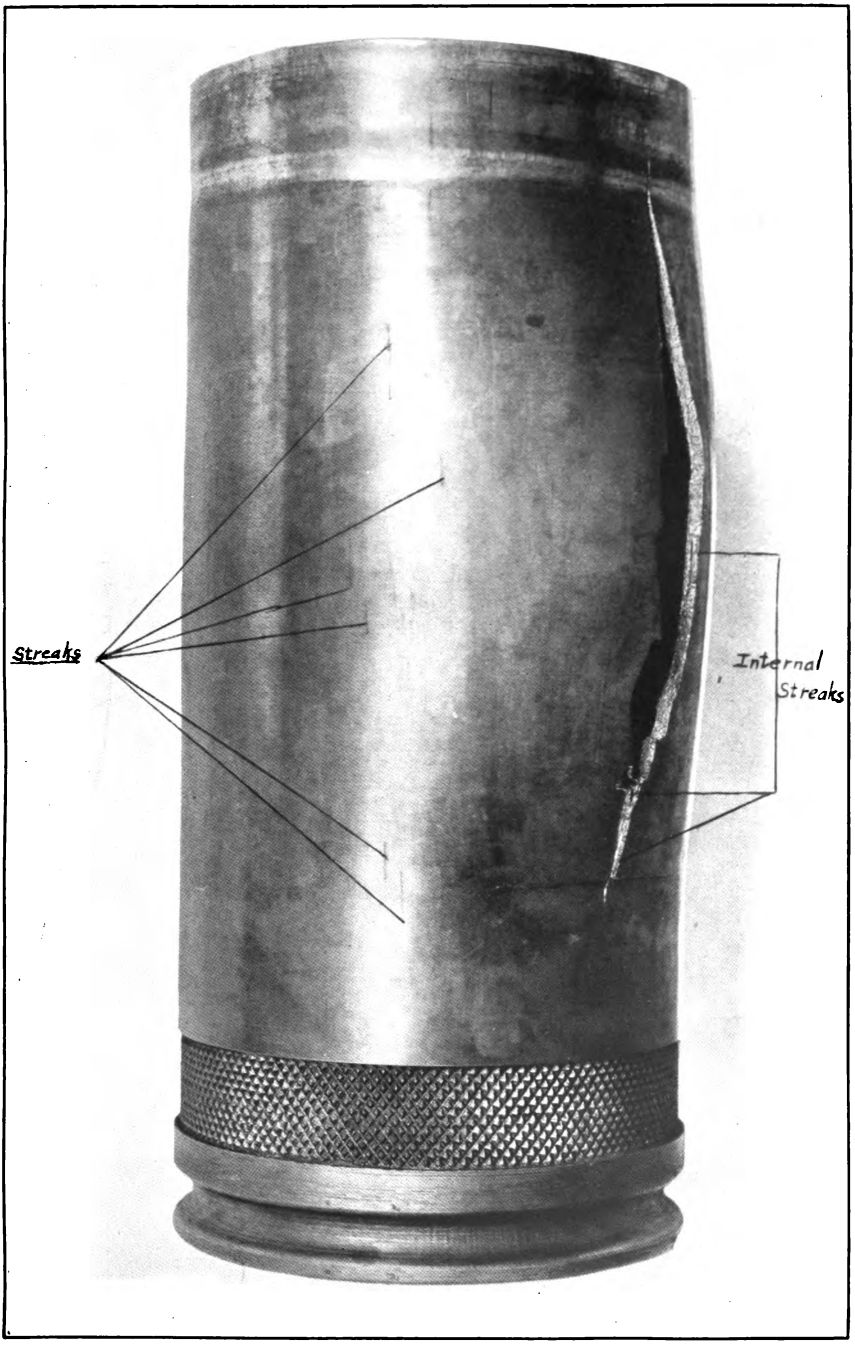
Diameter of piston, 5 inches.

Sectional area, 19.65 square inches.

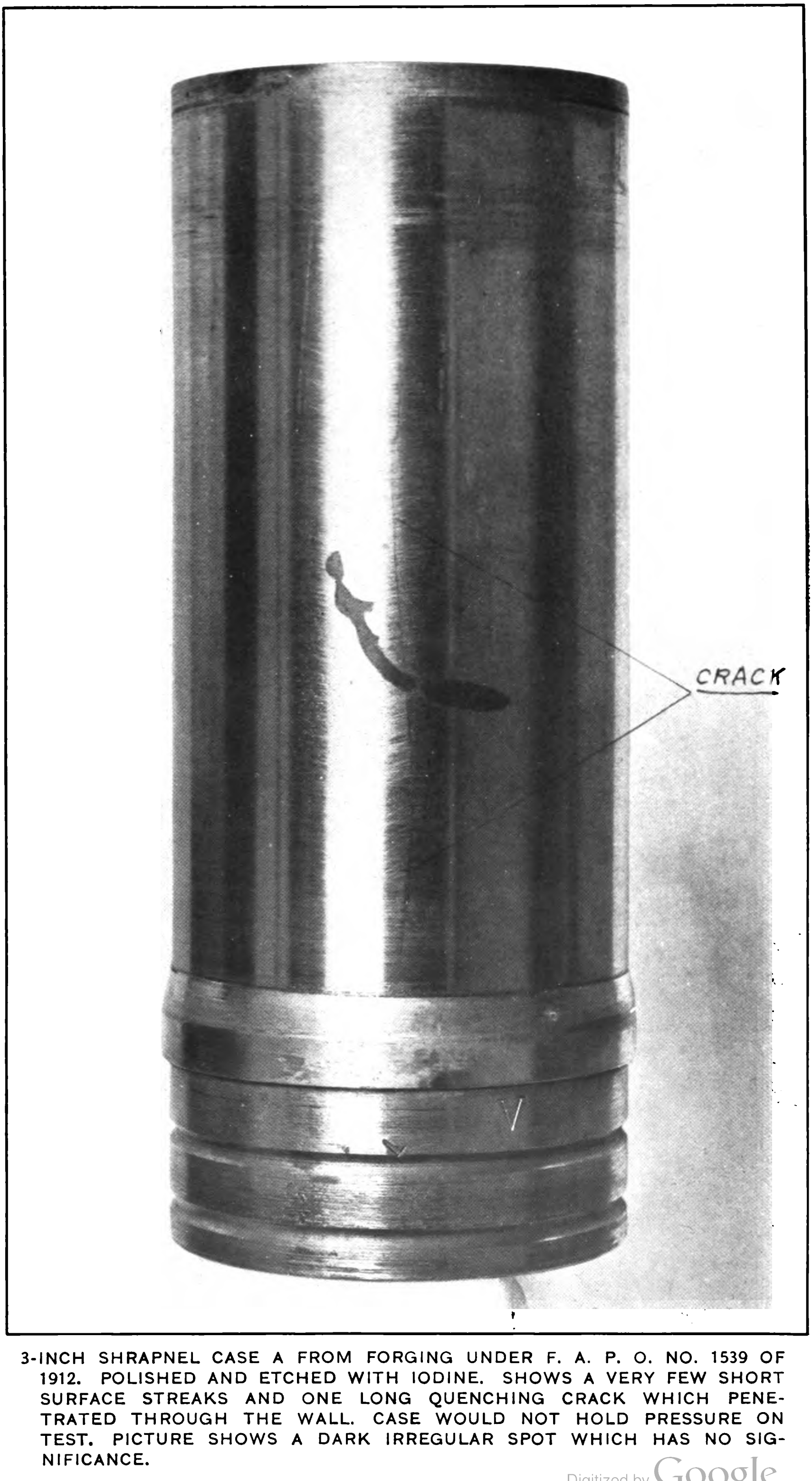
Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	5.90	
70,000	3,560	58,400	5.93	
85,000	4,330	71,000	5.93	
106,000	5,400	88,300	....	
115,000	5,860	96,000	5.94	
118,000	6,010	98,500	5.94	
122,000	6,215	101,800	....	Elastic limit.
140,300	7,150	117,000	....	Ultimate strength.



6-INCH SHRAPNEL CASE D. LOT 3-5352-13. FROM LOT THAT FAILED ON RETEST. POLISHED AND ETCHED WITH IODINE. SHOWS NUMEROUS SHORT STREAKS ON SURFACE.



6-INCH SHRAPNEL CASE D AFTER FRACTURE. FRACTURE SHOWS INTERNAL BRIGHT STREAKS.



3-INCH SHRAPNEL CASE A FROM FORGING UNDER F. A. P. O. NO. 1539 OF 1912. POLISHED AND ETCHED WITH IODINE. SHOWS A VERY FEW SHORT SURFACE STREAKS AND ONE LONG QUENCHING CRACK WHICH PENETRATED THROUGH THE WALL. CASE WOULD NOT HOLD PRESSURE ON TEST. PICTURE SHOWS A DARK IRREGULAR SPOT WHICH HAS NO SIGNIFICANCE.

Marks on case, A 124.
3-inch shrapnel case made from forging.
Outside diameter of case, 2.970 inches.
Inside diameter of case, 2.614 inches.
Bored out for a length of 5.80 inches.
Depth inside, 7 inches.
Length over all, outside, 7.40 inches.
Length from top to top edge of band groove, 5.65 inches.
Entered testing cylinder, 1 inch.
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.

Crack in case. Blew out water through crack when pressure was applied.

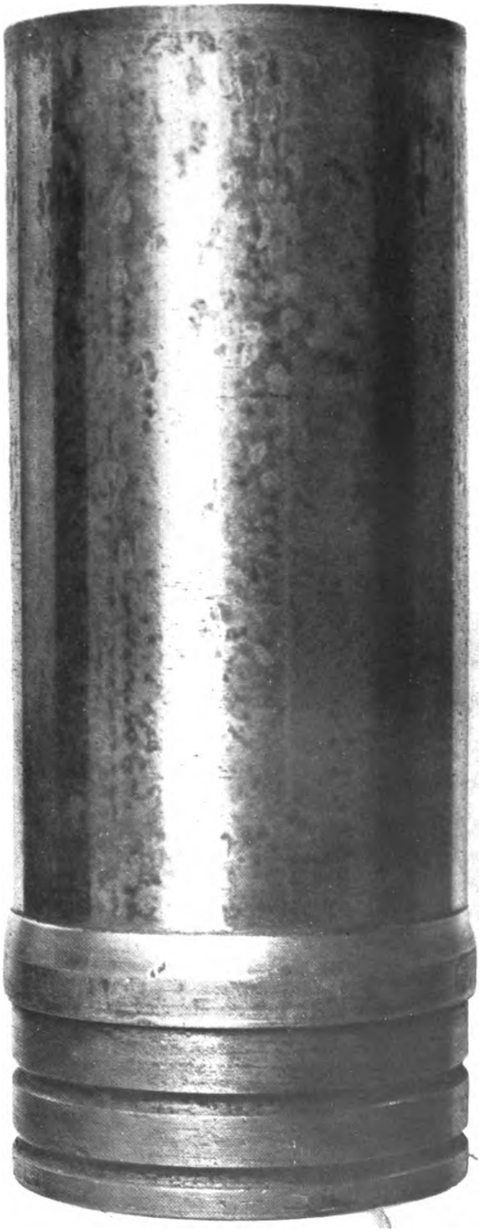
Marks on case, B 121.
3-inch shrapnel case made from forging.
Outside diameter of case, 2.97 inches.
Inside diameter of case, 2.63 inches.
Length of threaded section at top (not threaded).
Bored out for a depth of 5.50 inches.
Depth inside, 7 inches.
Length over all, outside, 7.40 inches.
Length from top to top edge of band groove, 5.65 inches.

Case entered testing cylinder 1 inch, leaving 4.50 inches length of reduced thickness of walls exposed to the interior pressure of the test.

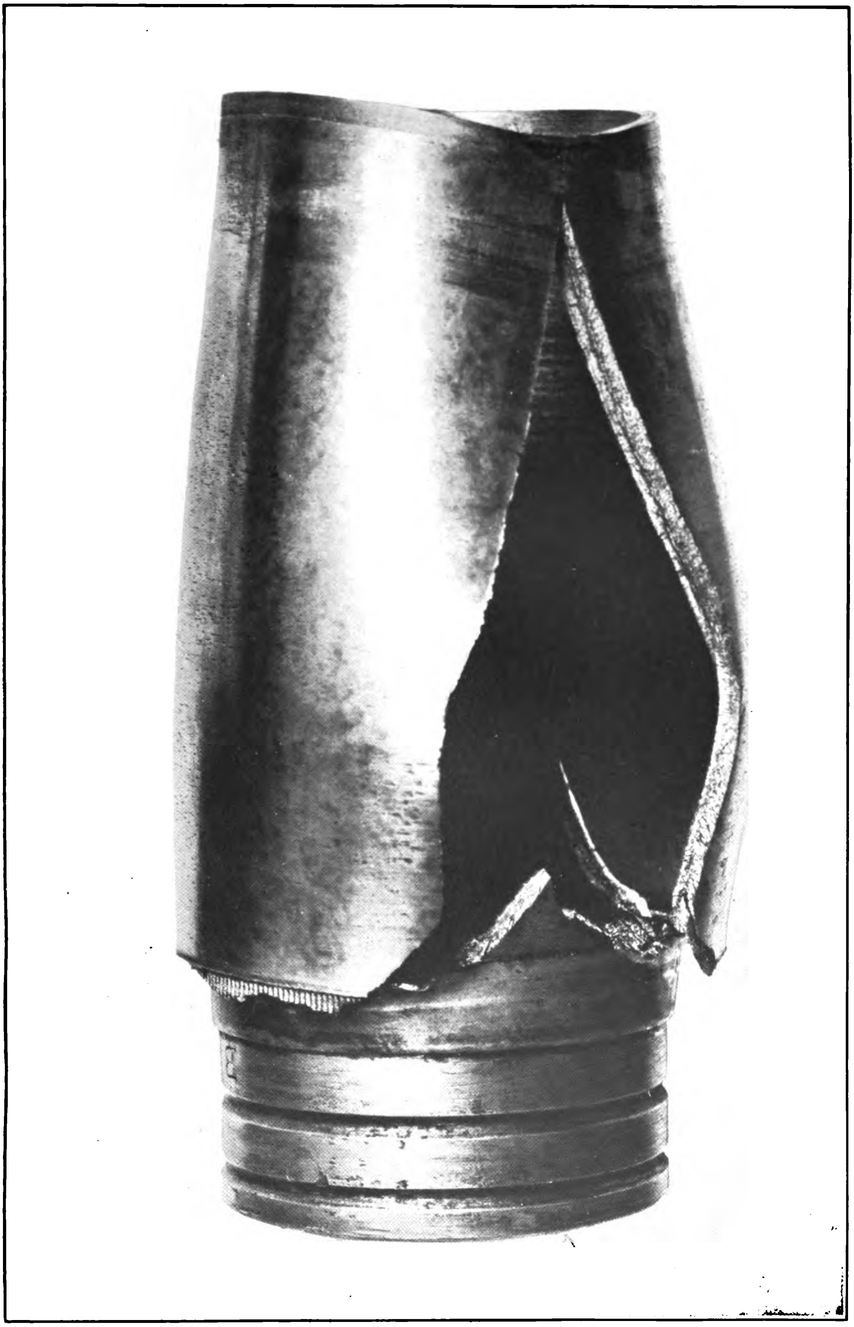
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
No streaks in case.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.97	
3,000	556	4,290	2.97	
5,000	927	7,150	2.97	
10,000	1,854	14,310	2.97	
15,000	2,782	21,480	2.97	
20,000	3,710	28,620	2.97	
25,000	4,640	35,800	2.97	
30,000	5,570	43,000	2.97	
35,000	6,490	50,100	2.97	
40,000	7,420	57,300	2.97	
45,000	8,350	64,500	2.97	
50,000	9,280	71,600	2.97	
55,000	10,200	78,800	2.97	
60,000	11,120	85,900	2.97	
108,200	20,070	155,300	....	Ultimate strength.

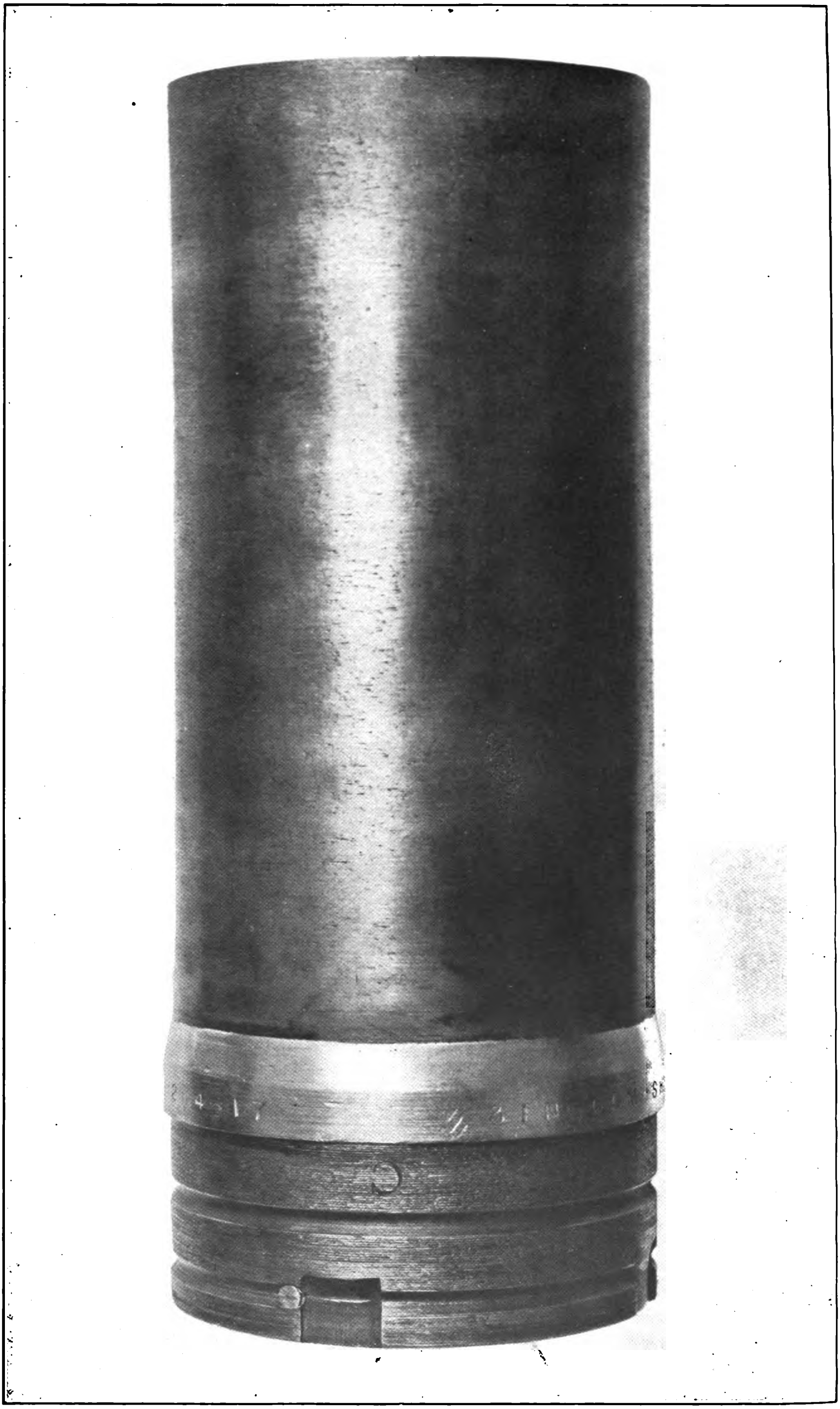
No streaks in fracture.



3-INCH SHRAPNEL CASE B FROM FORGING UNDER F. A. P. O. NO. 2972 OF 1913. POLISHED AND ETCHED WITH IODINE. NO STREAKS DEVELOPED. MOTTLED APPEARANCE DUE TO OVERETCHING.



3-INCH SHRAPNEL CASE B AFTER FRACTURE. FRACTURE SHOWED NO INTERNAL STREAKS.



3-INCH SHRAPNEL CASE C FROM FORGINGS UNDER F. A. P. O. NO. 3973 OF 1913. POLISHED AND ETCHED WITH IODINE. SHOWS NO STREAKS.

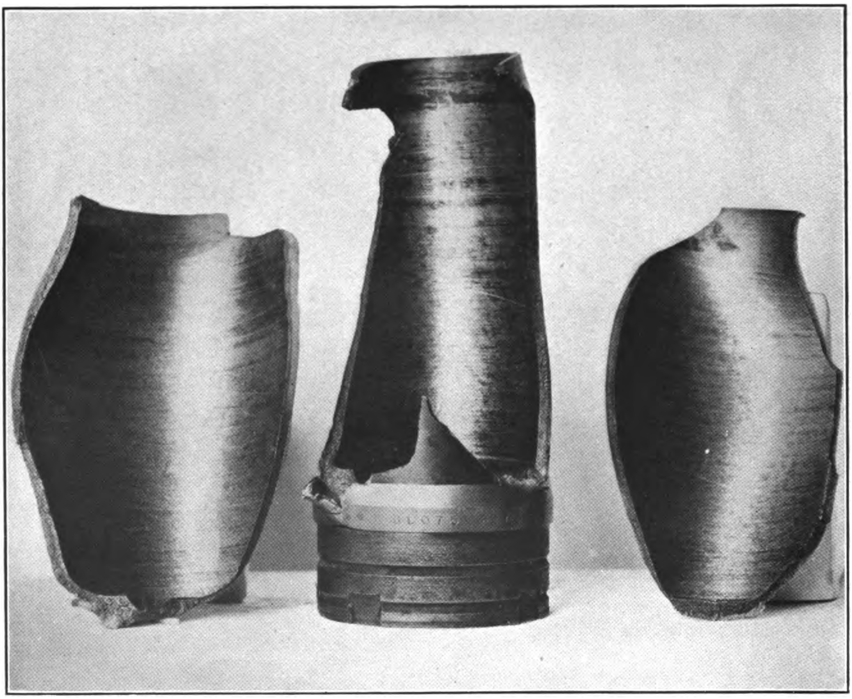
21-1

rging, lot No. 124.
ches.
hes.
es.

nches.
f band groove, 5.65 inches.
h.
es.
nches.

		Exterior diameter of case (inches).	Remarks.
	0	2.962	
	290	2.964	
	150	2.964	
	310	2.964	
	480	2.9645	
	,620	2.965	
	35,800	2.966	
	43,000	2.966	
	50,100	2.967	
	57,300	2.9675	
	64,500	2.9685	
	71,600	2.970	
	78,800	2.970	
	85,900	2.970	
	93,100	2.970	
	100,100	2.9705	
20	107,500	2.975	
40	114,600	2.988	
890	153,500	....	Ultimate strength.

in fracture.



3-INCH SHRAPNEL CASE C AFTER FRACTURE. FRACTURE SHOWS NO STREAKS. CASE RUPTURED INTO THREE PIECES.

21-2

Marks on case, C.
3-inch shrapnel case made from forging, lot No. 124.
Outside diameter of case, 2.962 inches.
Inside diameter of case, 2.623 inches.
Bored out for length of 5.50 inches.
Depth inside, 7 inches.
Length over all, outside, 7.40 inches.
Length from top to top edge of band groove, 5.65 inches.
Entered testing cylinder 1 inch.
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
No streaks in case.

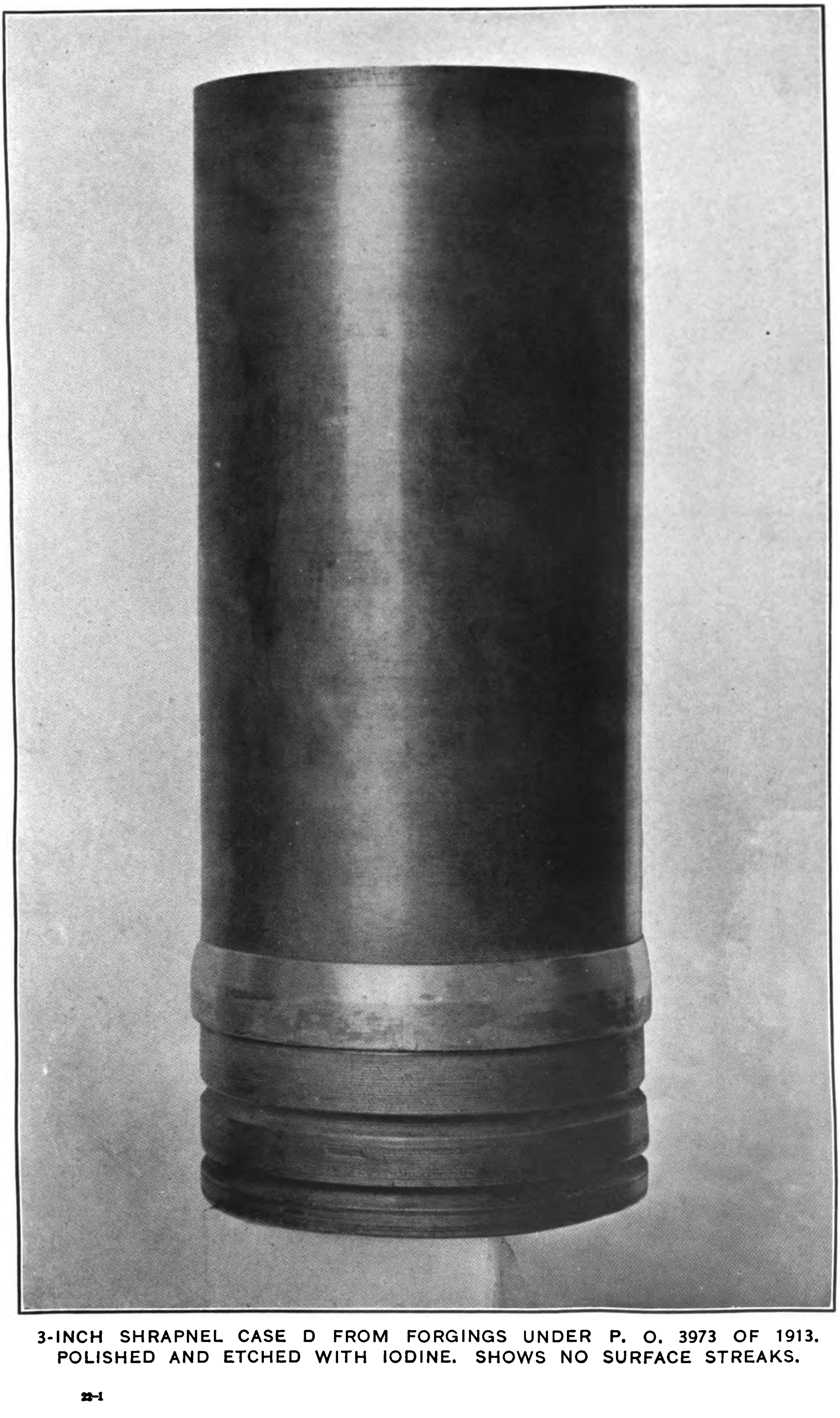
Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.962	
3,000	556	4,290	2.964	
5,000	927	7,150	2.964	
10,000	1,854	14,310	2.964	
15,000	2,782	21,480	2.9645	
20,000	3,710	28,620	2.965	
25,000	4,640	35,800	2.966	
30,000	5,570	43,000	2.966	
35,000	6,490	50,100	2.967	
40,000	7,420	57,300	2.9675	
45,000	8,350	64,500	2.9685	
50,000	9,280	71,600	2.970	
55,000	10,200	78,800	2.970	
60,000	11,120	85,900	2.970	
65,000	12,060	93,100	2.970	
70,000	12,980	100,100	2.9705	
75,000	13,920	107,500	2.975	
80,000	14,840	114,600	2.988	
107,200	19,890	153,500	....	Ultimate strength.

No streaks in fracture.

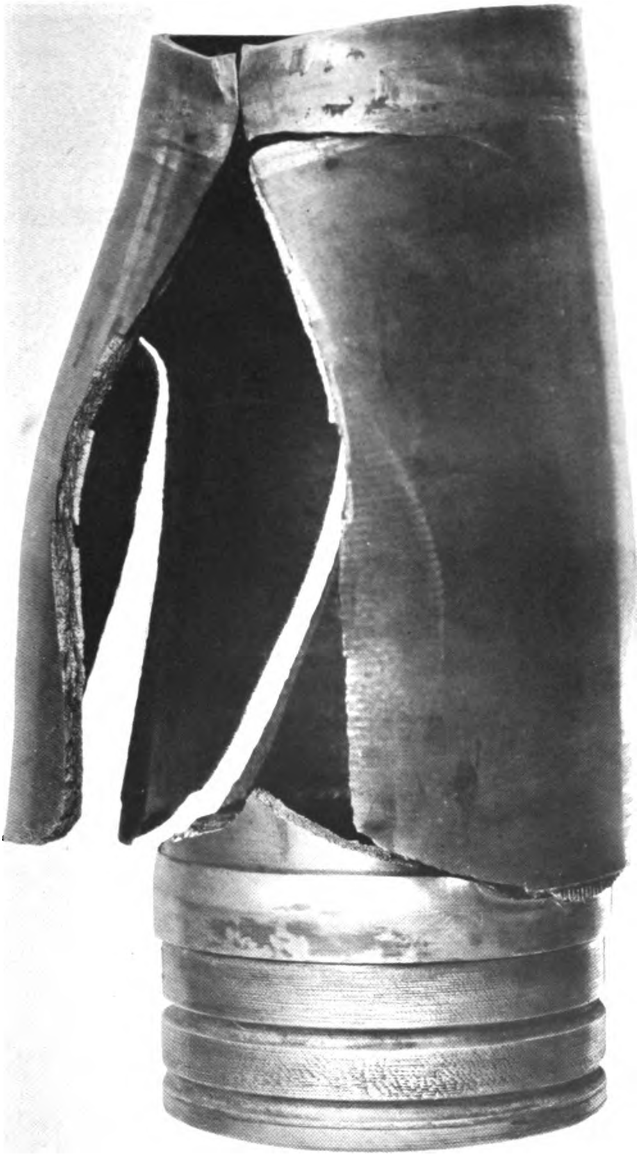
Marks on case, D.
3-inch shrapnel case made from forgings, lot No. 122.
Outside diameter of case, 2.97 inches.
Inside diameter of case, 2.63 inches.
Bored out for a length of 5.50 inches.
Depth inside, 7 inches.
Length over all, outside, 7.40 inches.
Length from top to top edge of band groove, 5.65 inches.
Entered testing cylinder, 1 inch.
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
No streaks in case.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.97	
3,000	556	4,290	2.97	
5,000	927	7,150	2.97	
10,000	1,854	14,310	2.975	
15,000	2,782	21,480	2.975	
20,000	3,710	28,620	2.975	
25,000	4,640	35,800	2.975	
30,000	5,570	43,000	2.975	
35,000	6,490	50,100	2.975	
40,000	7,420	57,300	2.975	
45,000	8,350	64,500	2.975	
50,000	9,280	71,600	2.975	
55,000	10,200	78,800	2.975	
60,000	11,120	85,900	2.970	
113,700	21,080	163,000	....	Ultimate strength.

No streaks in fracture.

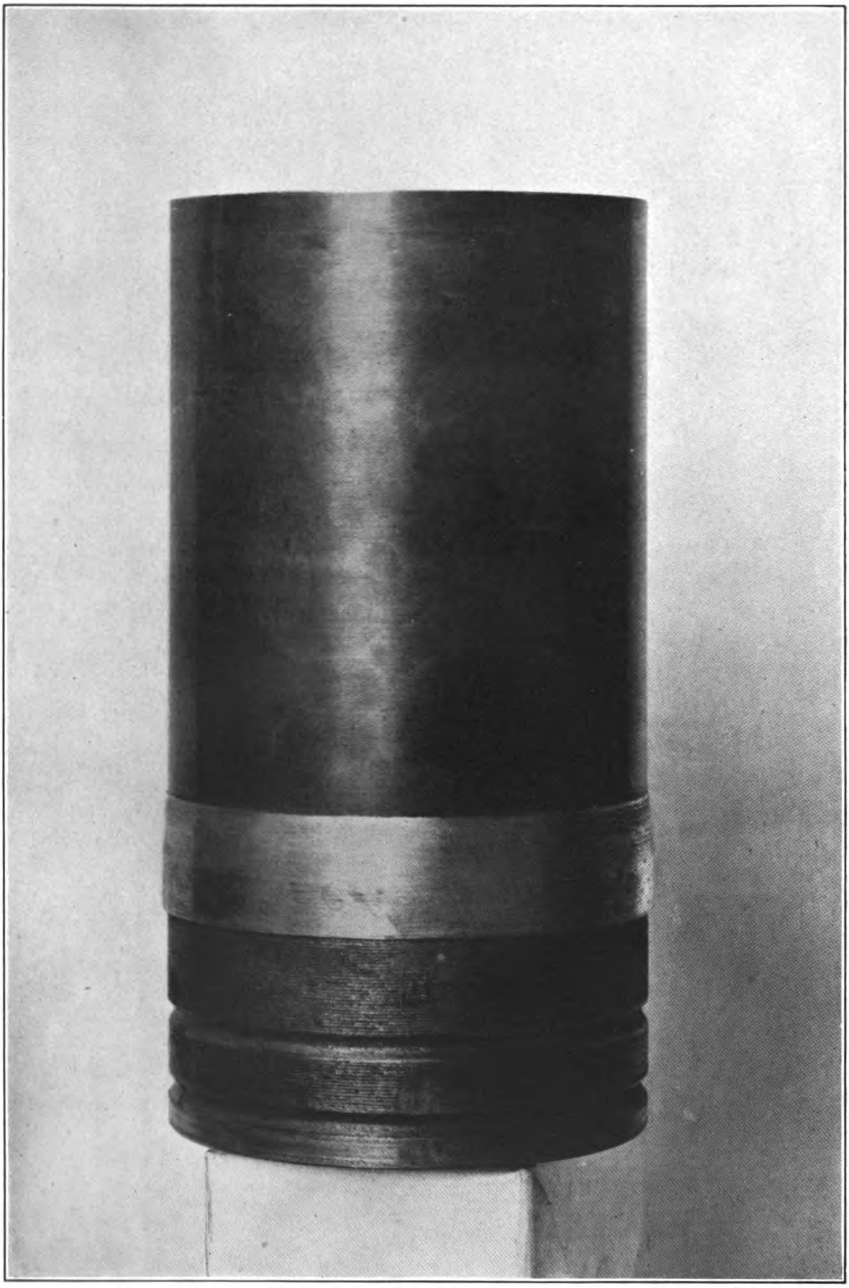


3-INCH SHRAPNEL CASE D FROM FORGINGS UNDER P. O. 3973 OF 1913. POLISHED AND ETCHED WITH IODINE. SHOWS NO SURFACE STREAKS.

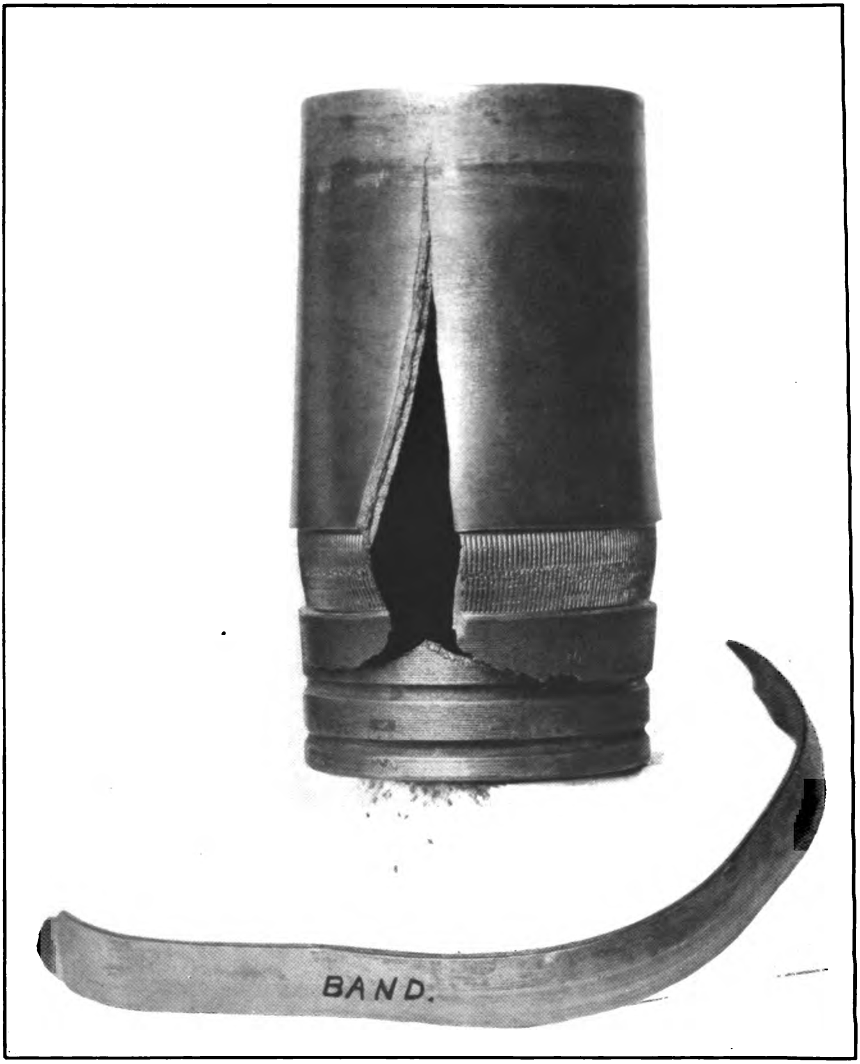


3-INCH SHRAPNEL CASE D AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS.

22-2



3-INCH SHRAPNEL CASE E FROM FORGINGS FOR NAVY DEPARTMENT. POLISHED AND ETCHED WITH IODINE. SHOWS NO SURFACE STREAKS.



3-INCH SHRAPNEL CASE E AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS. FRACTURE STARTED AT BAND SEAT.

Marks on case, E 4 $\frac{AB}{41}$.

3-inch shrapnel case made from forgings for the Navy Department.
Outside diameter of case, 2.960 inches.
Inside diameter of case, 2.632 inches.
Length of threaded section at top, 0.50 inch.
Bored out for a length of 4.70 inches.
Depth inside, 5.25 inches.
Length over all, outside, 5.70 inches.
Length from top to top edge of band groove, 3.60 inches.

Case entered testing cylinder 1 inch, leaving 3.70 inches length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
Case showed no streaks.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.960	These values calculated for thinnest section at band seat 0.080 inch. Values probably too high on account of location of band seat and proximity of internal and external reinforcing shoulders.
3,000	556	9,150	....	
5,000	927	15,230	2.9621	
10,000	1,854	30,500	2.9635	
15,000	2,782	45,800	2.9645	
20,000	3,710	61,000	2.9655	
25,000	4,640	76,300	2.966	
30,000	5,570	91,600	2.9675	
35,000	6,490	106,800	2.9685	
40,000	7,420	122,000	2.9692	
45,000	8,350	137,300	2.970	
50,000	9,280	152,700	2.9705	
55,000	10,200	167,800	2.9725	
60,000	11,120	183,000	2.9735	
65,000	12,060	198,300	2.974	
70,000	12,980	213,500	2.975	
75,000	13,920	229,000	2.976	
80,900	15,000	247,000	....	Ultimate strength.

Fractured at band seat, where thickness of wall was reduced. No streaks.

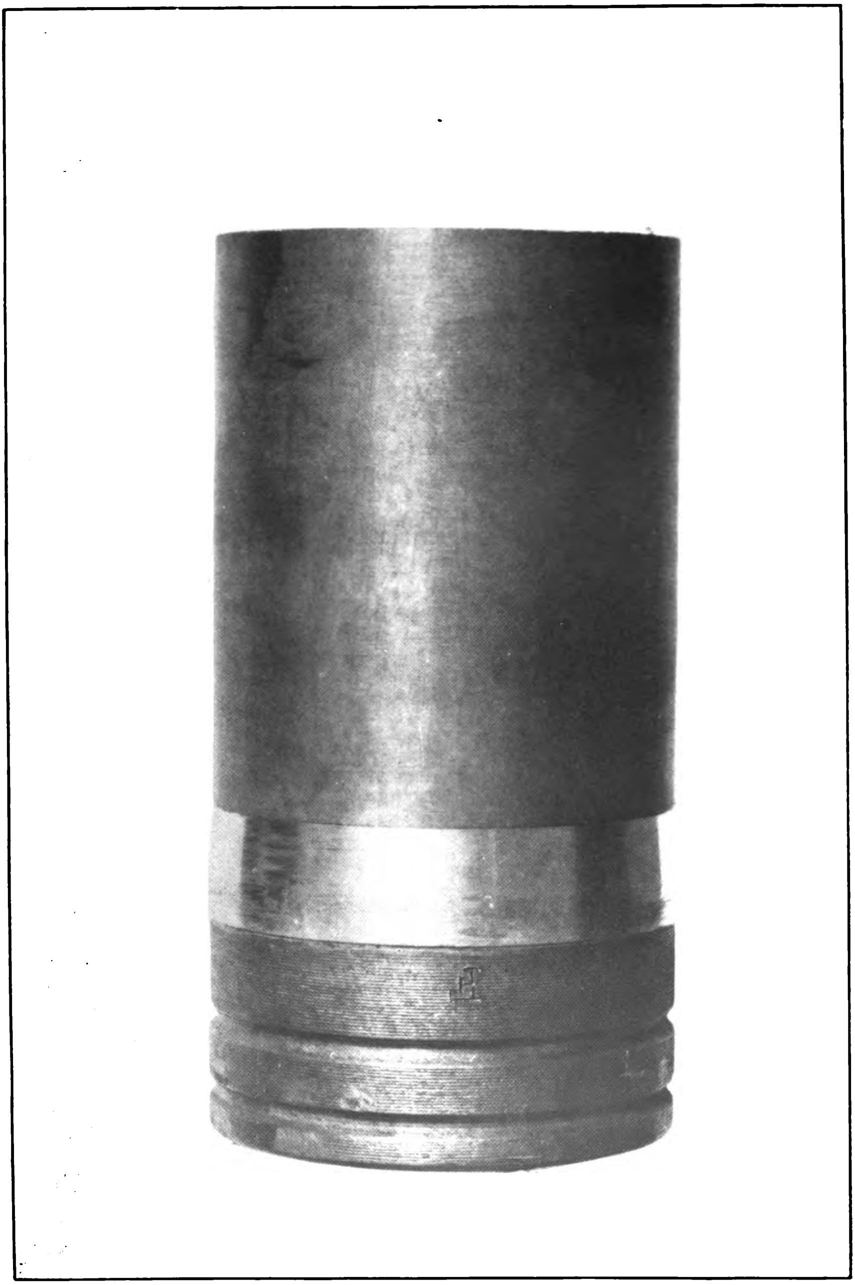
Marks on case, F 3 $\frac{\text{AB.}}{44}$

3-inch shrapnel case made from forgings for the Navy Department.
Outside diameter of case, 2.959 inches.
Inside diameter of case, 2.635 inches.
Length of threaded section at top, 0.50 inch.
Bored out for a length of 4.70 inches.
Depth inside, 5.25 inches.
Length over all, outside, 5.73 inches.
Length from top to top edge of band groove, 3.60 inches.

Case entered testing cylinder 1 inch, leaving 3.70 inches length of reduced thickness of walls exposed to the interior pressure of the test.

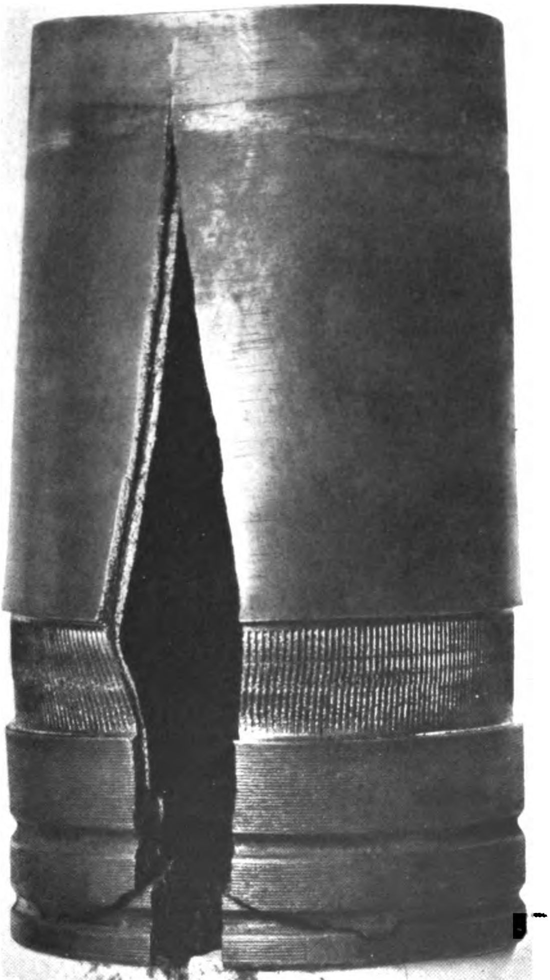
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
Case showed no streaks.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.959	
3,000	526	9,150	2.960	
5,000	927	15,230	2.9615	
10,000	1,854	30,500	2.9625	
15,000	2,782	45,800	2.9630	
20,000	3,710	61,000	2.9640	
25,000	4,640	76,300	2.9650	
30,000	5,570	91,600	2.9680	
35,000	6,490	106,800	2.971	
40,000	7,420	122,000	2.971	
45,000	8,350	137,300	2.973	Fracture at band seat where thickness of wall was reduced. Thickness of wall where fracture started, 0.080. Fracture showed no streaks.
50,000	9,280	152,700	2.973	
55,000	10,200	167,800	2.974	
60,000	11,120	183,000	2.976	
65,000	12,060	198,300	2.980	
70,000	12,980	213,500	2.984	
75,000	13,920	229,000	....	
88,900	16,670	274,000	....	Ultimate strength.

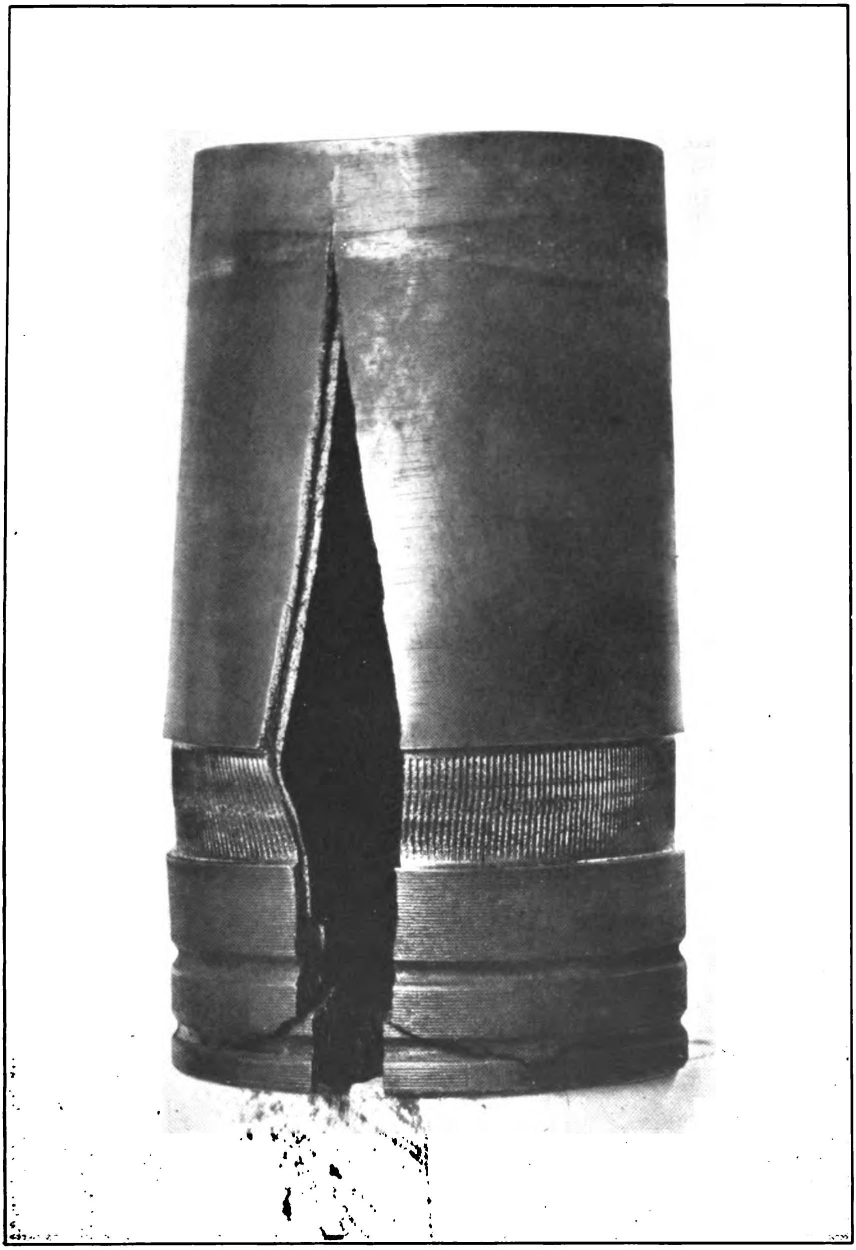


3-INCH SHRAPNEL CASE F FROM FORGINGS FOR NAVY DEPARTMENT. POLISHED AND ETCHED WITH IODINE. SHOWS NO SURFACE STREAKS.

24–1

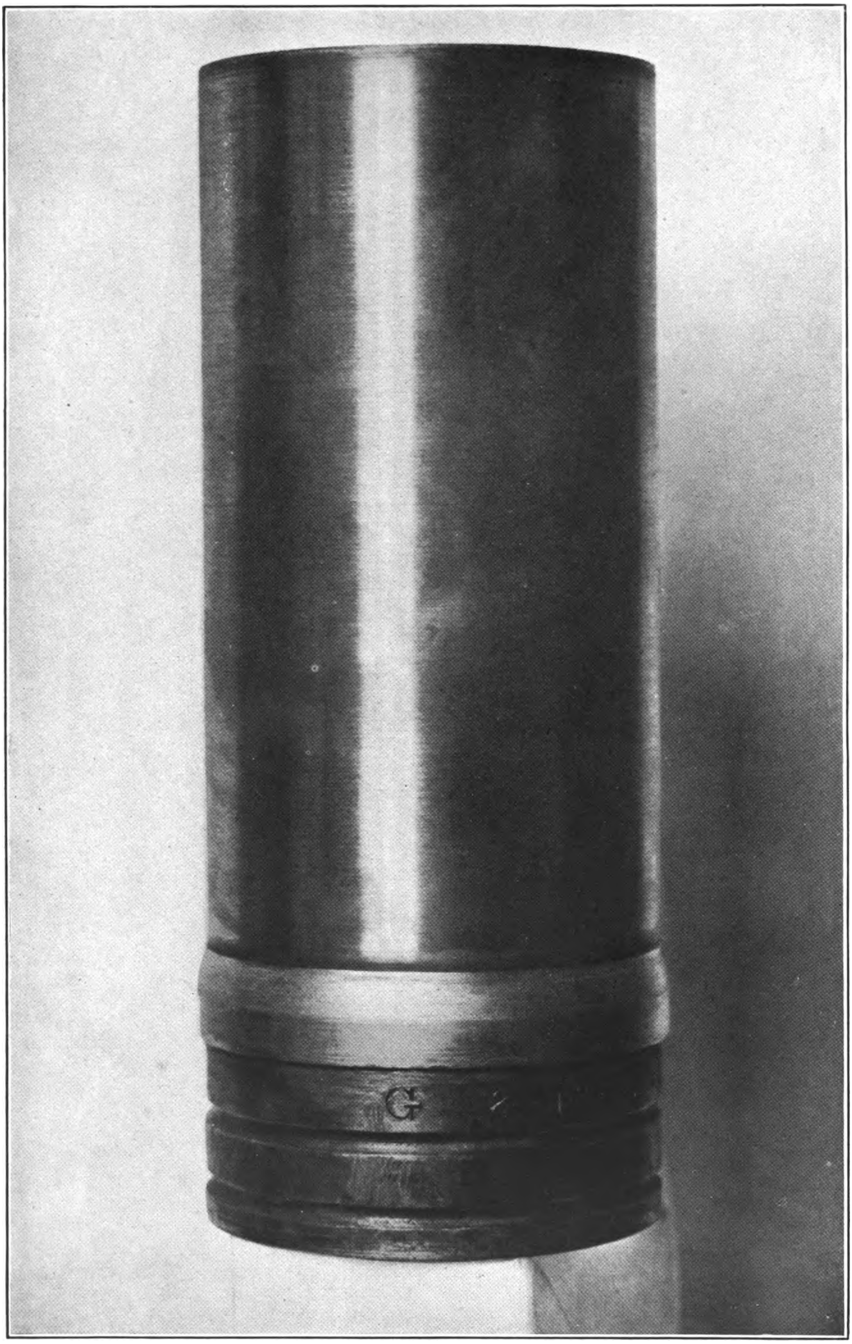


3-INCH SHRAPNEL CASE F AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS. FRACTURE STARTED AT BAND SEAT.

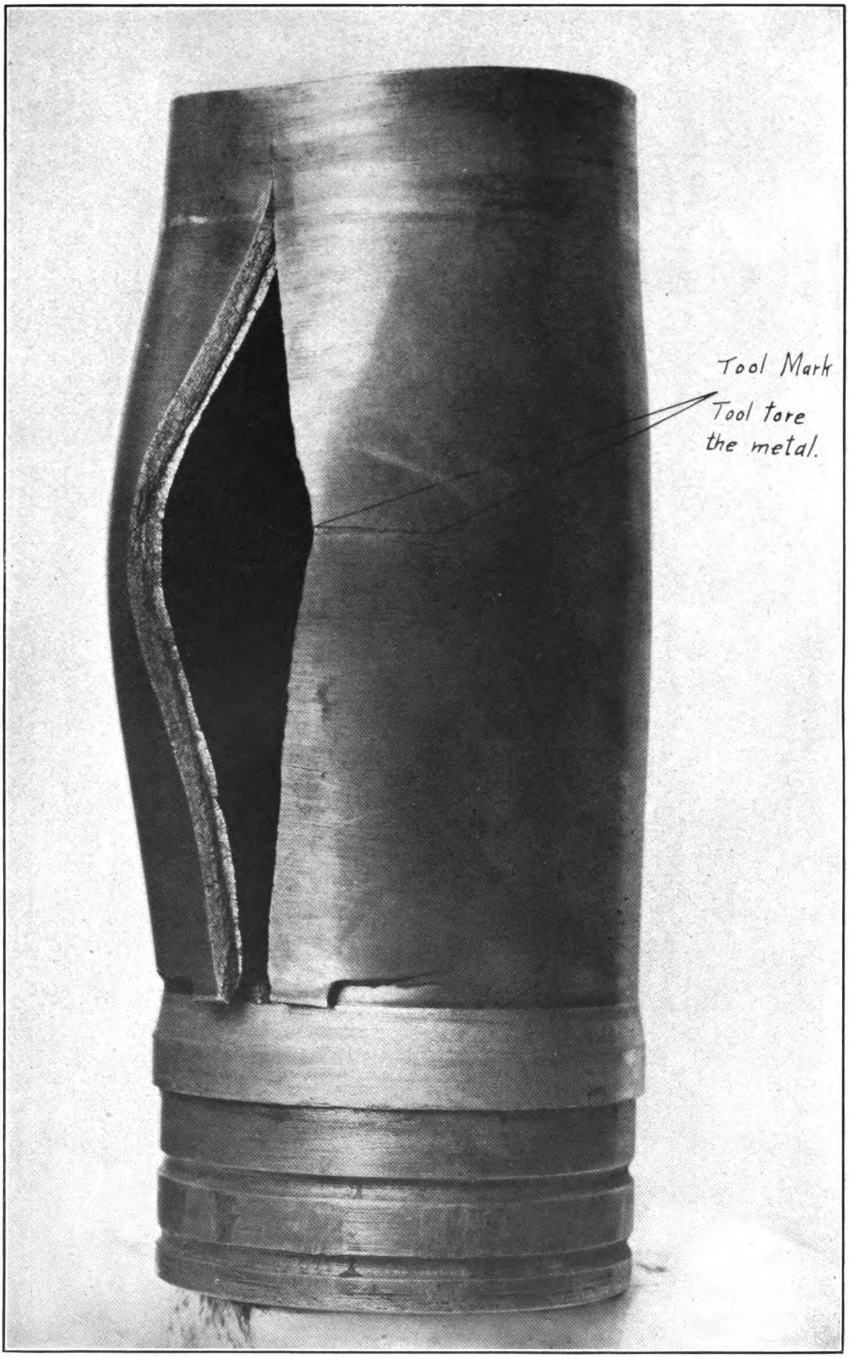


3-INCH SHRAPNEL CASE F AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS. FRACTURE STARTED AT BAND SEAT.

24-2



3-INCH SHRAPNEL CASE G MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK UNDER F. A. P. O. 1220. POLISHED AND ETCHED WITH IODINE. SHOWS NO SURFACE STREAKS.



3-INCH SHRAPNEL CASE G AFTER FRACTURE. FRACTURE SHOWS NO INTERNAL STREAKS. FRACTURE STARTED AT TOOL MARK.

Marks on case, G 2–1220–12.

3-inch shrapnel case made at Frankford Arsenal from bar stock.

These cases are free from seams.

Outside diameter of case, 2.973 inches.

Inside diameter of case, 2.621 inches.

Length of threaded section at top, 0.50 inch.

Bored out for a length of 5.53 inches.

Depth inside, 7 inches.

Length over all, outside, 7.45 inches.

Length from top to top edge of band groove, 5.63 inches.

Case entered testing cylinder 1 inch, leaving 4.53 inches length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 2.62 inches.

Sectional area, 5.39 square inches.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.973	
3,000	556	4,140	2.973	
5,000	927	6,900	2.974	
10,000	1,854	13,800	2.975	
15,000	2,782	20,720	2.9755	
20,000	3,710	27,640	2.976	
25,000	4,640	34,550	2.9765	
30,000	5,570	41,500	2.9765	
35,000	6,490	48,350	2.977	No seams apparent in fracture. Broke at slight mark made by gauging tool.
40,000	7,420	55,300	2.978	
45,000	8,350	62,200	2.979	
50,000	9,280	69,100	2.980	
55,000	10,200	76,000	2.980	
60,000	11,120	82,800	2.981	
65,000	12,060	89,800	2.982	
70,000	12,980	96,600	2.983	
75,000	13,920	103,750	2.985	
80,000	14,840	110,600	2.987	
85,000	15,760	117,600	2.995	
97,400	18,050	134,400	....	Ultimate strength.

Marks on case, H.

3-inch shrapnel case made at Frankford Arsenal from bar stock.

Case shows bad streaks throughout the entire length.

Outside diameter of case, 2.965 inches.

Inside diameter of case, 2.624 inches.

Length of threaded section at top, 0.50 inch.

Bored out for a length of 5.50 inches.

Depth inside, 7 inches.

Length over all, outside, 7.45 inches.

Length from top to top edge of band groove, 5.65 inches.

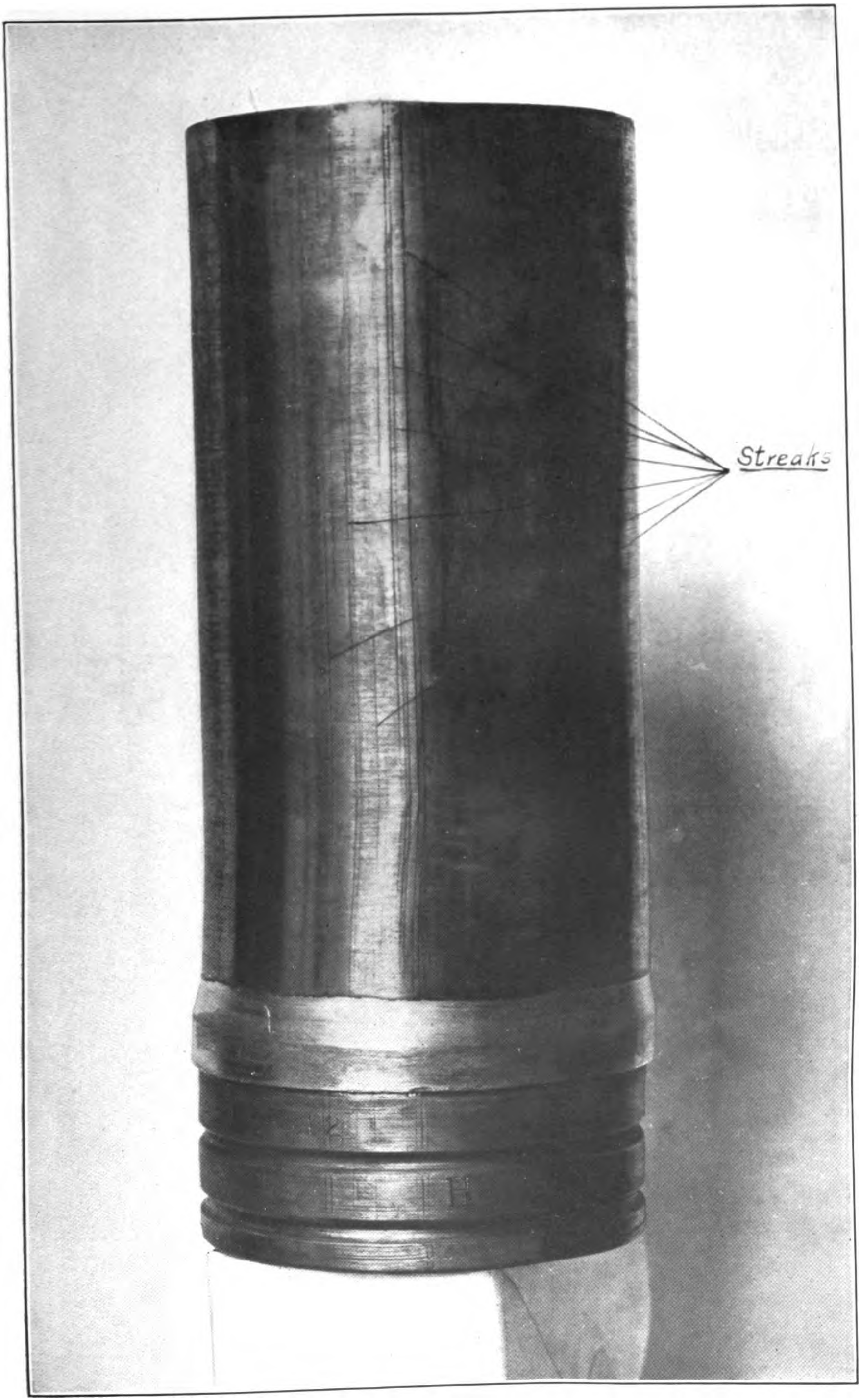
Case entered testing cylinder 1 inch, leaving 4.63 inches length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 2.62 inches.

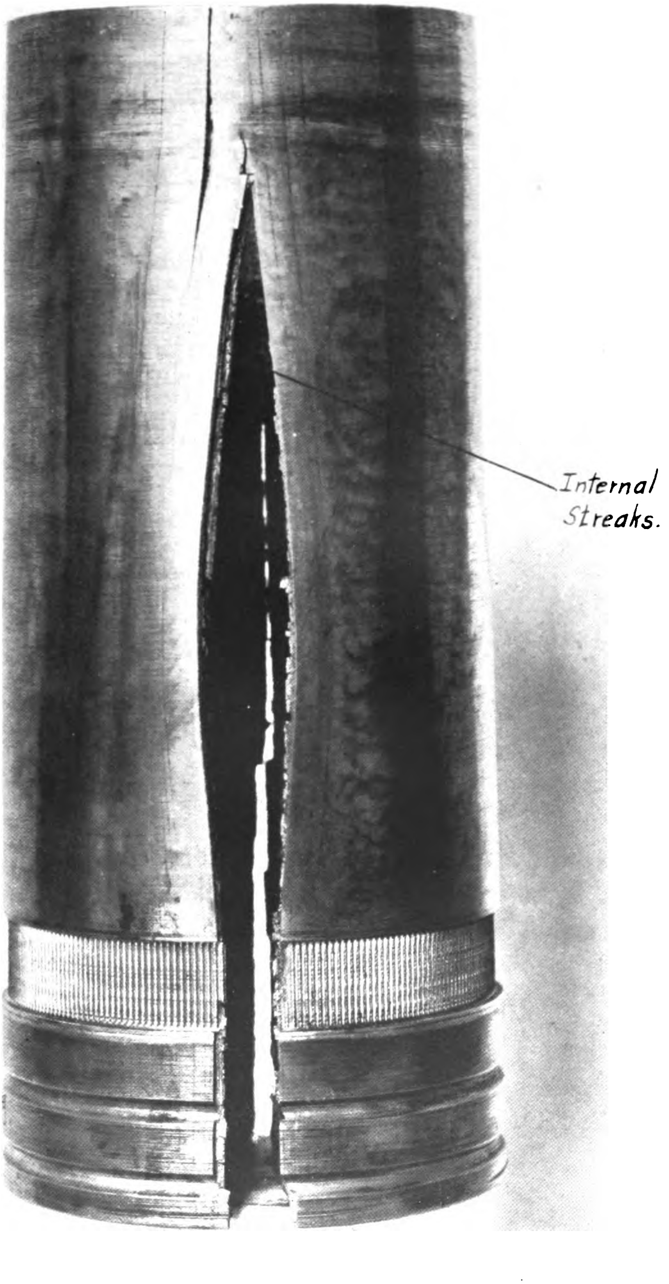
Sectional area, 5.39 square inches.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.965	
3,000	556	4,290	2.967	
5,000	927	7,150	2.968	
10,000	1,854	14,310	2.969	
15,000	2,782	21,480	2.969	
20,000	3,710	28,620	2.969	
25,000	4,640	35,800	2.971	
30,000	5,570	43,000	2.972	
35,000	6,490	50,100	2.9725	
40,000	7,420	57,300	2.973	
45,000	8,350	64,500	2.974	
50,000	9,280	71,600	2.974	
55,000	10,200	78,800	2.975	
60,000	11,120	85,900	2.975	
65,000	12,060	93,100	2.976	
70,000	12,980	100,100	2.977	
75,000	13,920	107,500	2.9785	
80,000	14,840	114,600	2.9785	
85,000	15,770	122,000	....	Ultimate strength.

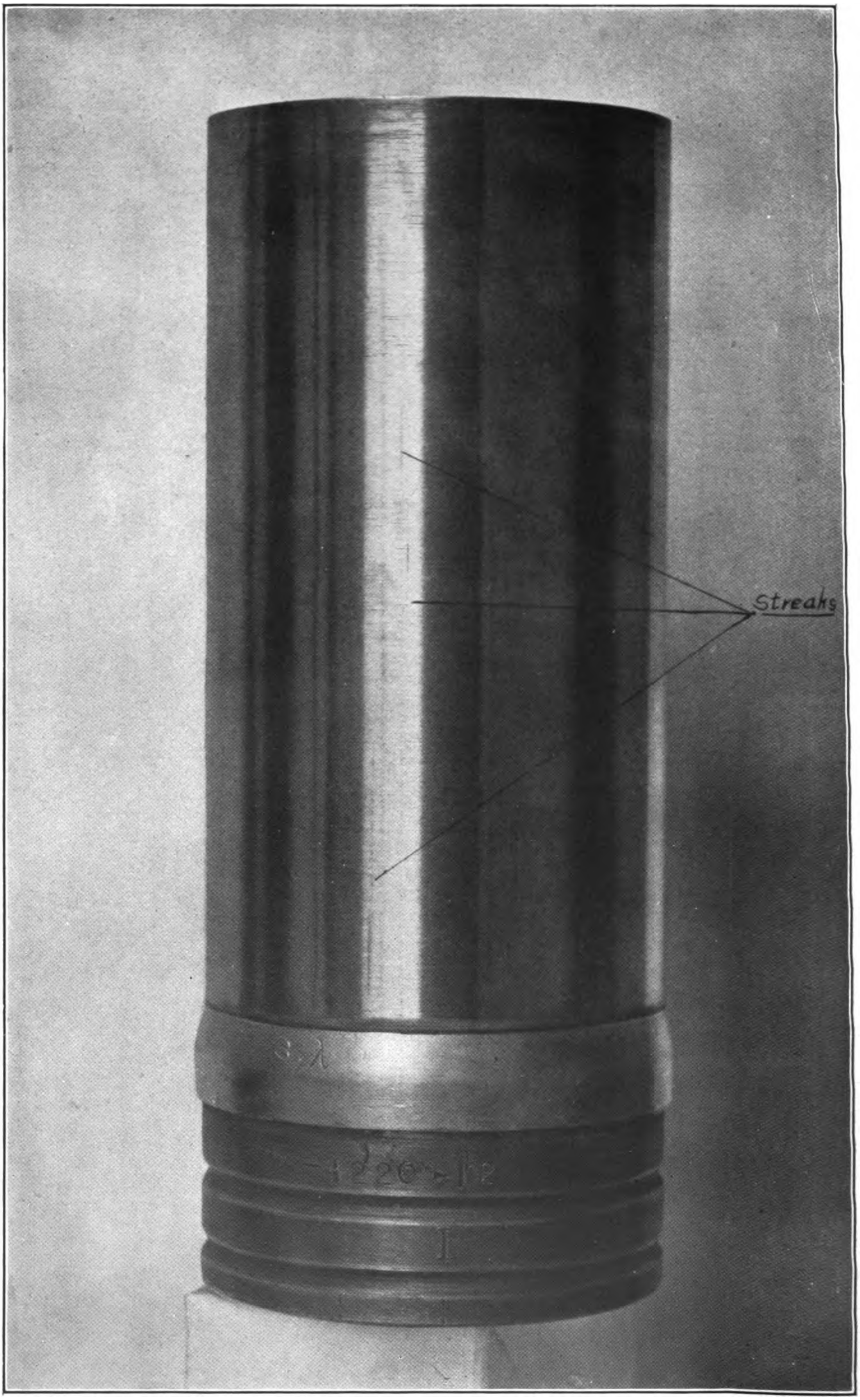
Fracture showed internal and external streak.



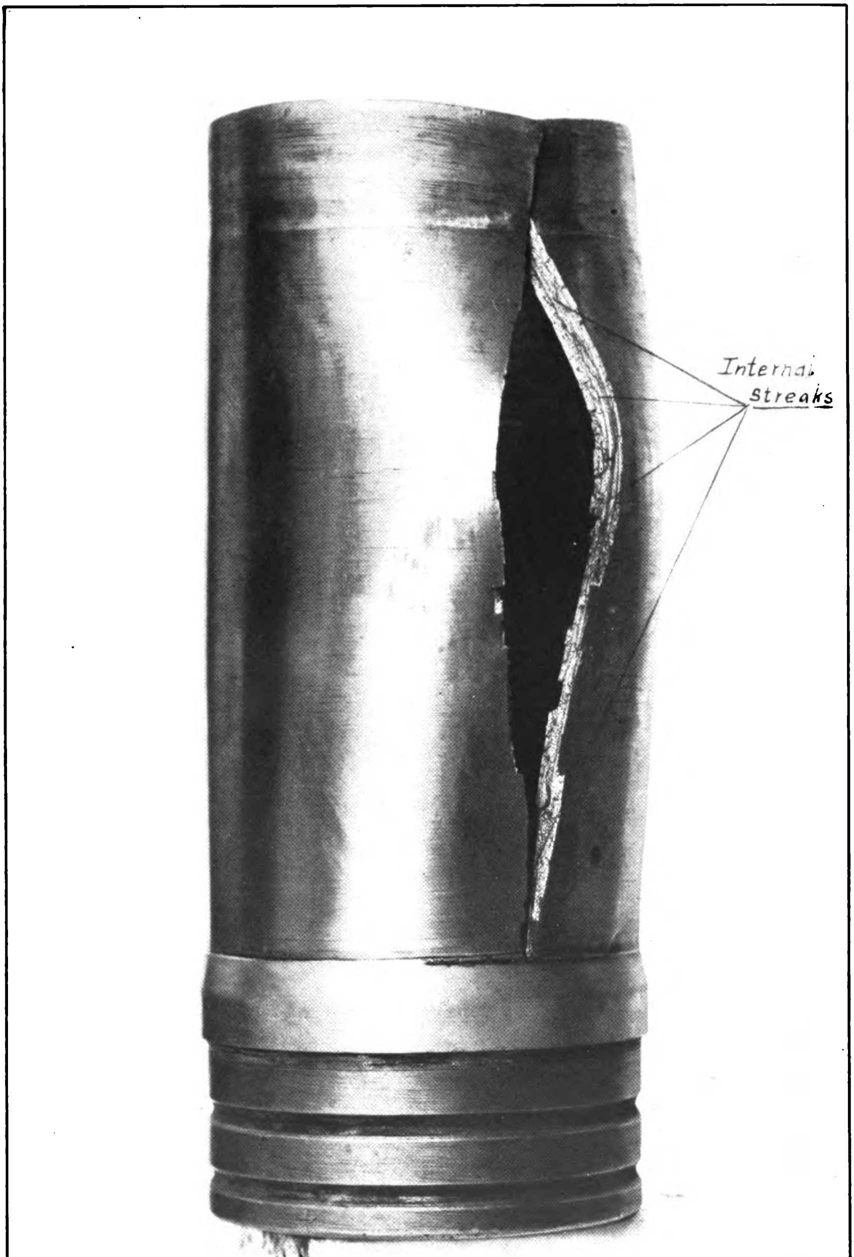
3-INCH SHRAPNEL CASE H MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK. THIS STOCK SHOWED LINES AFTER MACHINING. POLISHED AND ETCHED WITH IODINE. A GREAT MANY DEEP STREAKS RUNNING ENTIRE LENGTH OF CASE VISIBLE.



3-INCH SHRAPNEL CASE H AFTER FRACTURE. FRACTURE OCCURRED AT SURFACE LINE OR STREAK AND SHOWED INTERNAL STREAKS ALSO. CASE SPLIT THROUGH BASE AND FRACTURE CONTINUED PART WAY UP OPPOSITE SIDE.



3-INCH SHRAPNEL CASE I MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK FURNISHED ON F. A. P. O. NO. 1220. SAID TO BE WITHOUT SEAMS. POLISHED AND ETCHED WITH IODINE. SHOWED NUMEROUS SURFACE STREAKS BUT CASE WAS NOT NEARLY SO BADLY STREAKED AS CASE H.



3-INCH SHRAPNEL CASE 1 AFTER FRACTURE. FRACTURE OCCURRED AT SURFACE STREAK AND REVEALED INTERIOR STREAKS.

27-2

Marks on case, I 5–1220–12.

3-inch shrapnel case made at Frankford Arsenal from bar stock.

Outside diameter of case, 2.966 inches.

Inside diameter of case, 2.630 inches.

Length of threaded section at top, 0.50 inch.

Bored out for a length of 5.52 inches.

Depth inside, 7 inches.

Length over all, outside, 7.45 inches.

Length from top to top edge of band groove, 5.62 inches.

Case entered testing cylinder 1 inch, leaving 4.62 inches length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 2.62 inches.

Sectional area, 5.39 square inches.

Case was somewhat streaky.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.966	
3,000	556	4,350	2.966	
5,000	927	7,250	2.966	
10,000	1,854	14,500	2.9665	
15,000	2,782	21,780	2.967	
20,000	3,710	29,050	2.9675	
25,000	4,640	36,300	2.968	
30,000	5,570	43,600	2.9685	
35,000	6,490	50,800	2.969	
40,000	7,420	58,100	2.9695	
45,000	8,350	65,400	2.9705	
50,000	9,280	72,600	2.971	Fracture shows internal and external streaks.
55,000	10,200	79,800	2.9715	
60,000	11,120	87,000	2.9725	
65,000	12,060	94,400	2.973	
70,000	12,980	101,600	2.974	
75,000	13,920	109,000	2.9745	
80,000	14,840	116,100	2.976	
85,000	15,790	126,000	....	
89,800	16,650	130,300	....	Ultimate strength.

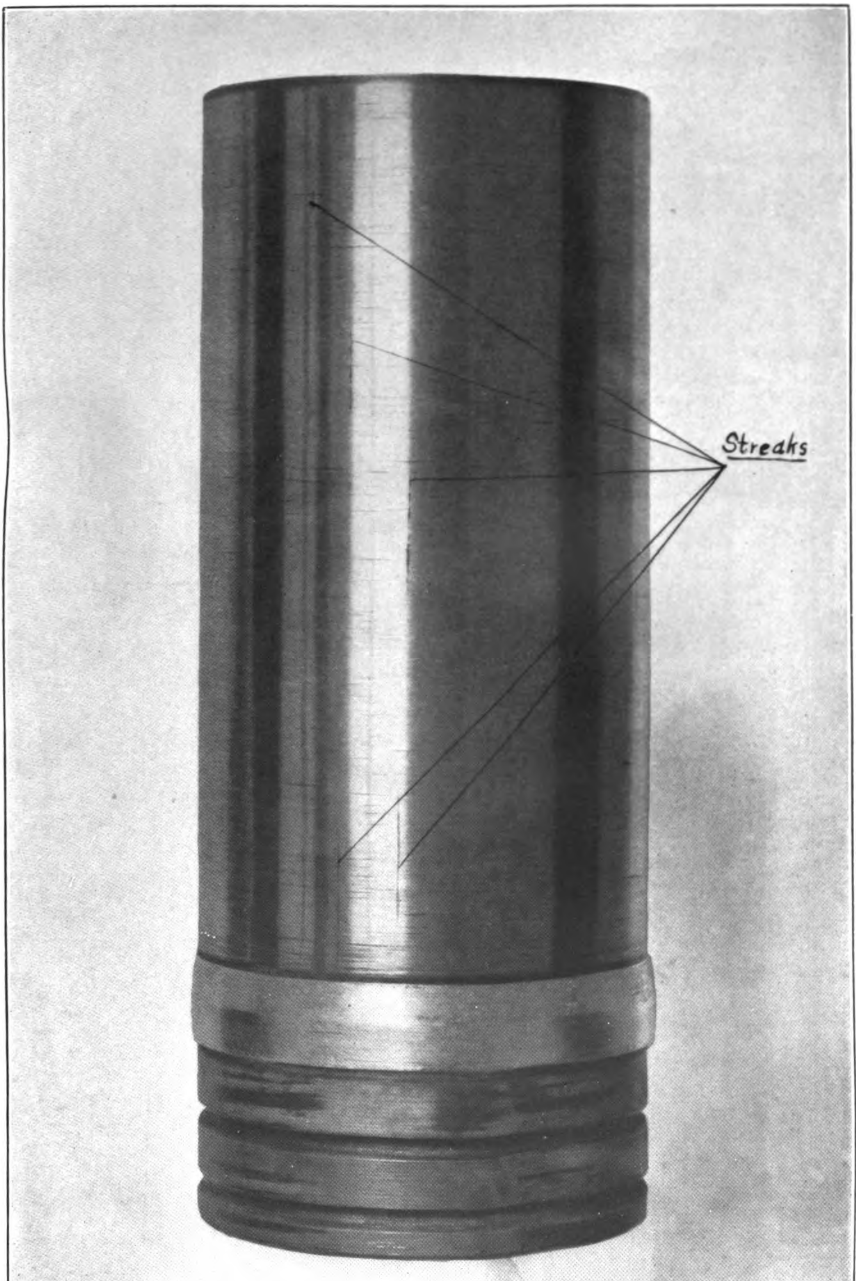
Marks on case, J.
3-inch shrapnel case made at Frankford Arsenal from bar stock.
Outside diameter of case, 2.973 inches.
Inside diameter of case, 2.63 inches.
Length of threaded section at top, 0.50 inch.
Bored out for a length of 5.50 inches.
Depth inside, 7.03 inches.
Length over all, outside, 7.45 inches.
Length from top to top edge of band groove, 5.68 inches.

Case entered testing cylinder 1 inch, leaving 4.68 inches length of reduced thickness of walls exposed to the interior pressures of the test.

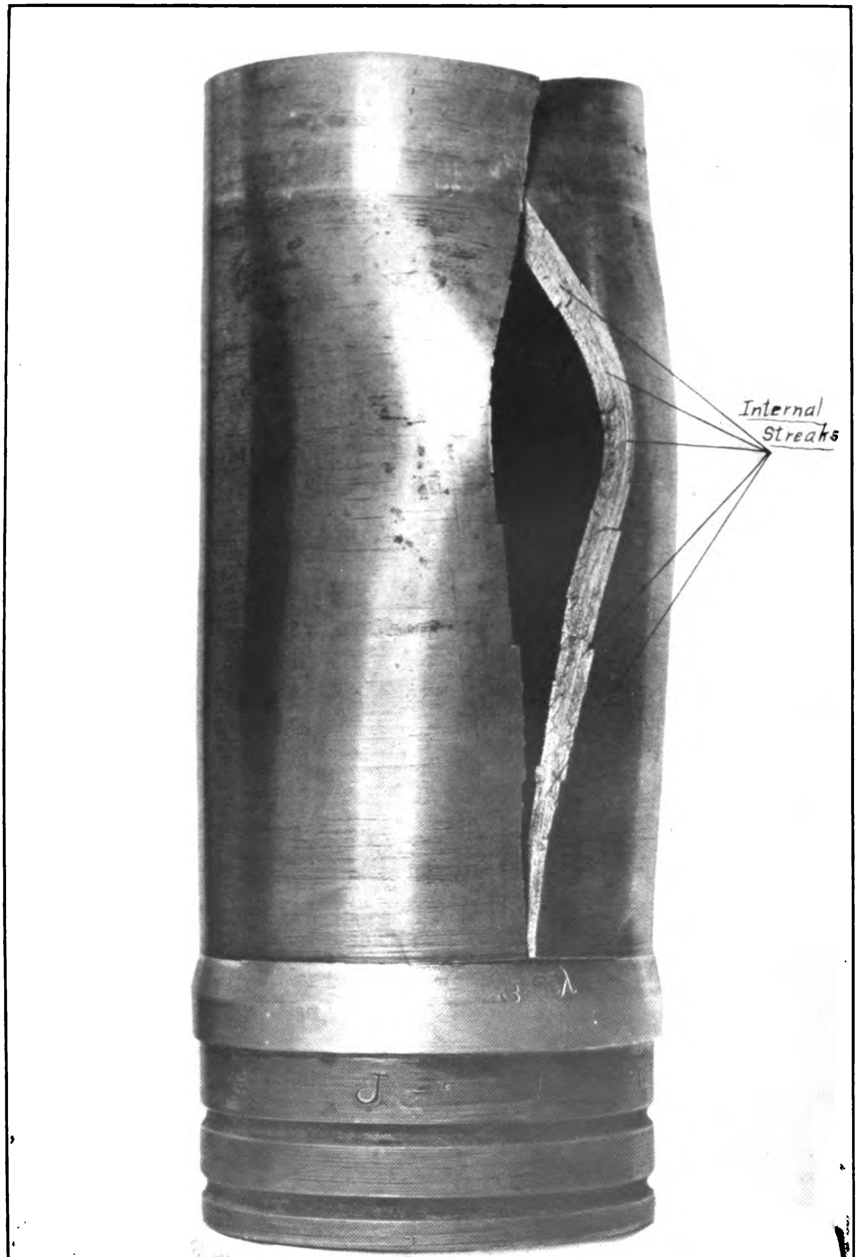
Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
Case showed bad streaks.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.973	
3,000	556	4,290	2.974	
5,000	927	7,150	2.974	
10,000	1,854	14,310	2.974	
15,000	2,782	21,480	2.9755	
20,000	3,710	28,620	2.976	
25,000	4,640	35,800	2.9765	
30,000	5,570	43,000	2.978	
35,000	6,490	50,100	2.9785	
40,000	7,420	57,300	2.979	
45,000	8,350	64,500	2.9795	
50,000	9,280	71,600	2.980	
55,000	10,200	78,800	2.9805	
60,000	11,120	85,900	2.981	
65,000	12,060	93,100	2.982	
70,000	12,980	100,100	2.9835	
75,000	13,920	107,500	2.984	
80,000	14,840	114,600	2.984	
85,000	15,790	122,000	2.986	
96,300	17,860	138,100	....	Ultimate strength.

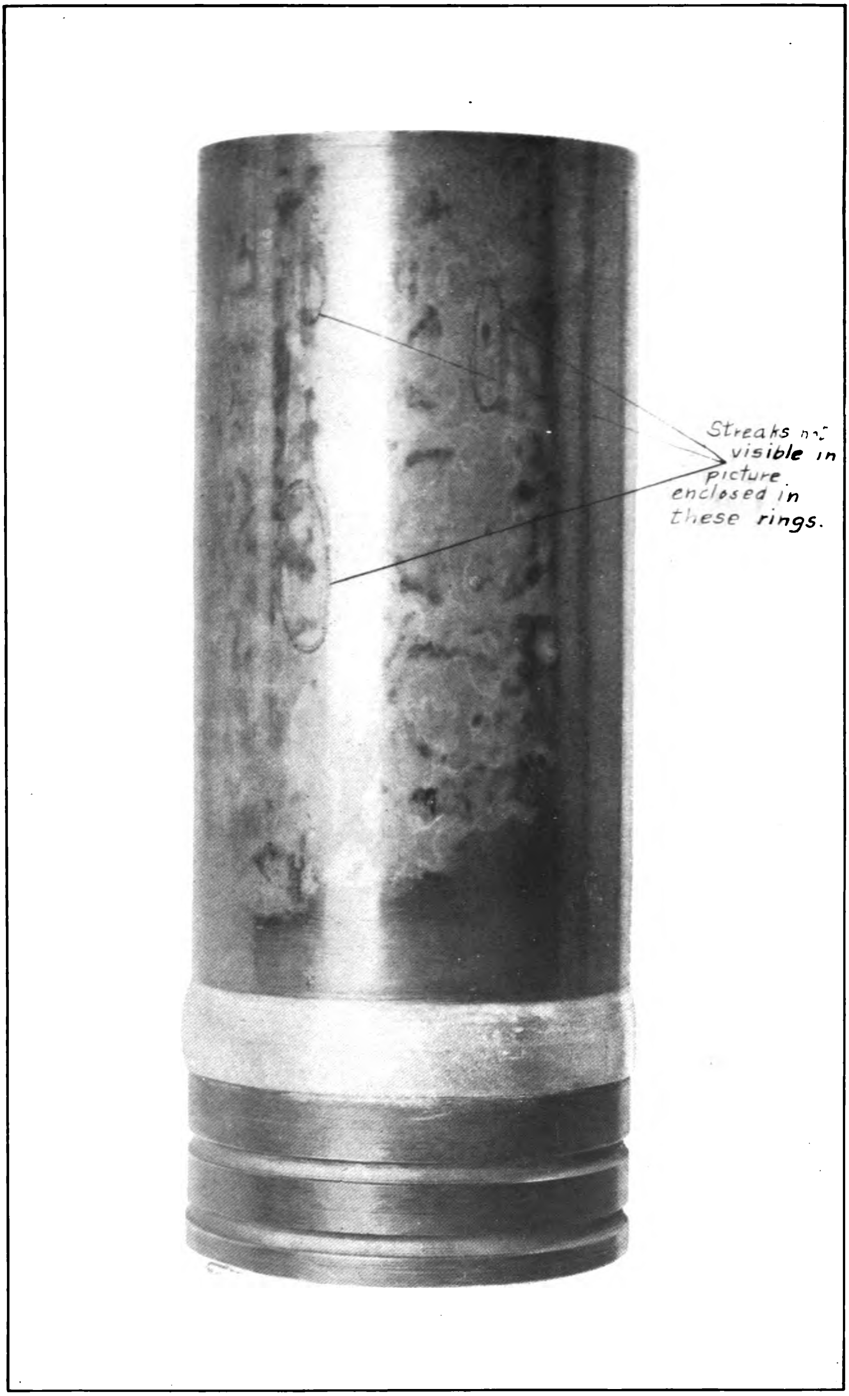
Fracture showed external and internal streaks.



3-INCH SHRAPNEL CASE J MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK ON F. A. P. O. NO. 1220. MATERIAL SAID TO SHOW LINES SIMILAR TO H. POLISHED AND ETCHED WITH IODINE. SHOWS NUMEROUS SURFACE STREAKS BUT NOT SO MANY AS CASE H.

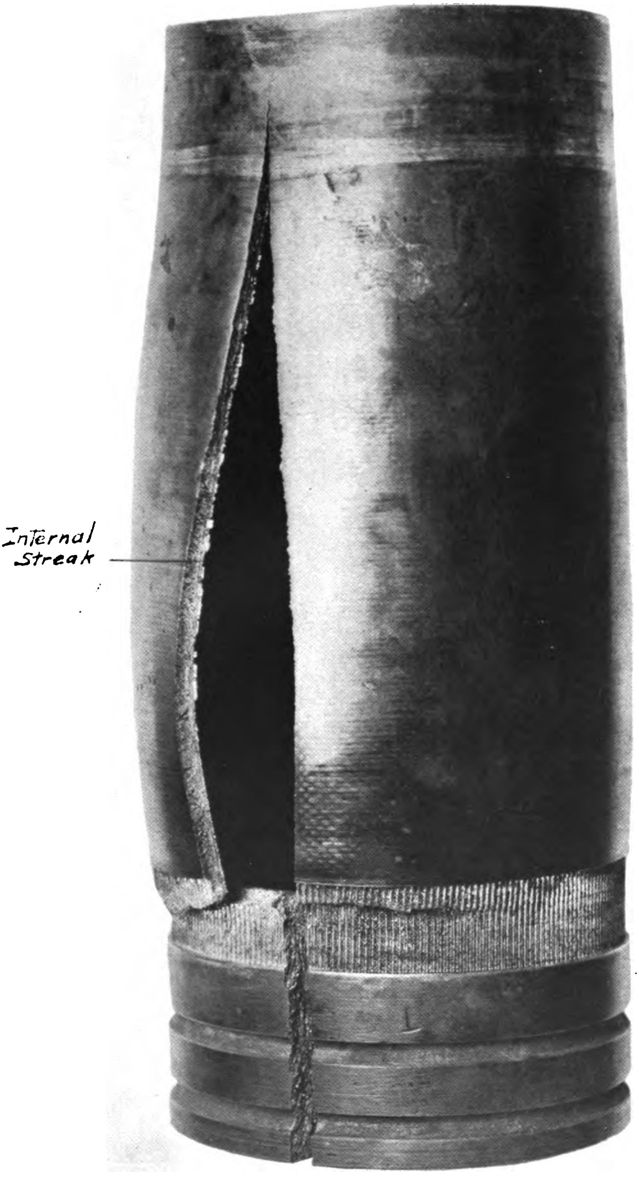


3-INCH SHRAPNEL CASE J AFTER FRACTURE. FRACTURE OCCURRED AT SURFACE STREAK AND SHOWS INTERNAL STREAKS.



Streaks not visible in picture enclosed in these rings.

2.95-INCH SHRAPNEL CASE K MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK. UNDER P. O. NO. 2731. POLISHED AND ETCHED WITH IODINE. NUMEROUS SHORT SURFACE STREAKS VISIBLE, SHOWN IN PICTURE SURROUNDED BY PENCIL MARKS. MOTTLED APPEARANCE OF CASE DUE TO OVERETCHING.



2.95-INCH SHRAPNEL CASE K AFTER FRACTURE. FRACTURE DID NOT OCCUR AT SURFACE STREAK, BUT REVEALED ALONG INTERNAL STREAK. CASE SPLIT THROUGH BASE.

Marks on case, K 2731.

2.95-inch shrapnel case made at Frankford Arsenal from bar stock.

Outside diameter of case, 2.92 inches.

Inside diameter of case, 2.63 inches.

Length of threaded section at top, 0.50 inch.

Bored out to a length of 5.50 inches.

Depth inside, 6.80 inches.

Length over all, outside, 7.14 inches.

Length from top to top edge of band groove, 5.37 inches.

Case entered testing cylinder 1 inch, leaving 4.50 inches length of reduced thickness of walls exposed to the interior pressures of the test.

Diameter of the piston, 2.62 inches.

Sectional area, 5.39 square inches.

Case had streaks.

Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.92	
3,000	556	5,040	2.925	
5,000	927	8,400	2.93	
10,000	1,854	16,820	2.93	
15,000	2,782	25,240	2.935	
20,000	3,710	33,650	2.935	
25,000	4,640	42,100	2.935	
30,000	5,570	50,500	2.94	
35,000	6,490	58,900	2.94	
40,000	7,420	67,300	2.945	
45,000	8,350	75,700	2.945	
50,000	9,280	84,150	2.945	
55,000	10,200	92,500	2.945	
60,000	11,120	100,900	2.945	
75,200	13,950	126,500	....	Ultimate strength.

Failed at an internal streak.

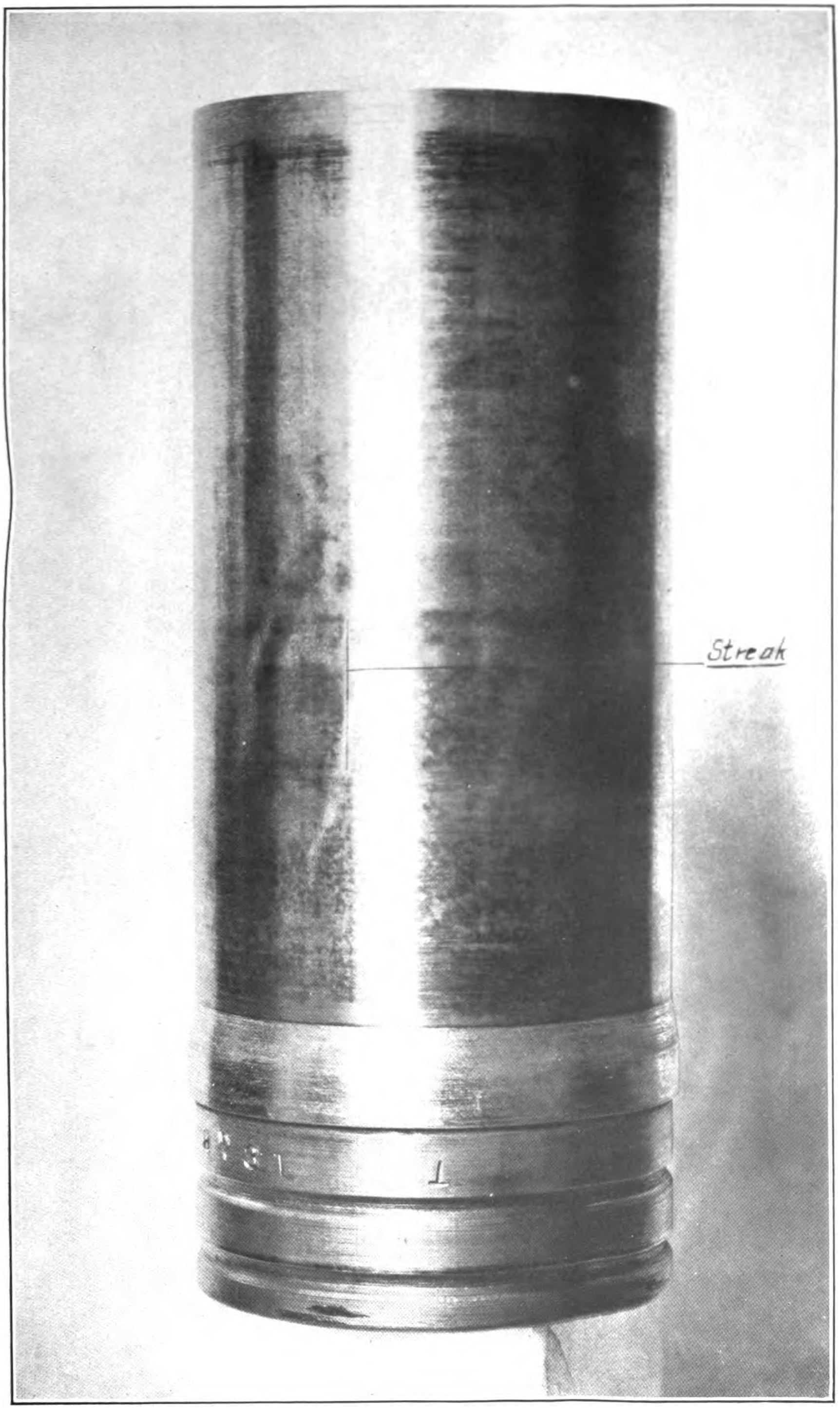
Marks on case, L 2731.
2.95-inch shrapnel case made at Frankford Arsenal from bar stock.
Outside diameter of case, 2.92 inches.
Inside diameter of case, 2.62 inches.
Length of threaded section at top, 0.50 inch.
Bored out for a length of 5.50 inches.
Depth inside, 6.80 inches.
Length over all, outside, 7.15 inches.
Length from top to top edge of band groove, 5.38 inches.

Case entered testing cylinder 1 inch, leaving 4.50 inches length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 2.62 inches.
Sectional area, 5.39 square inches.
Case contained longitudinal streaks.

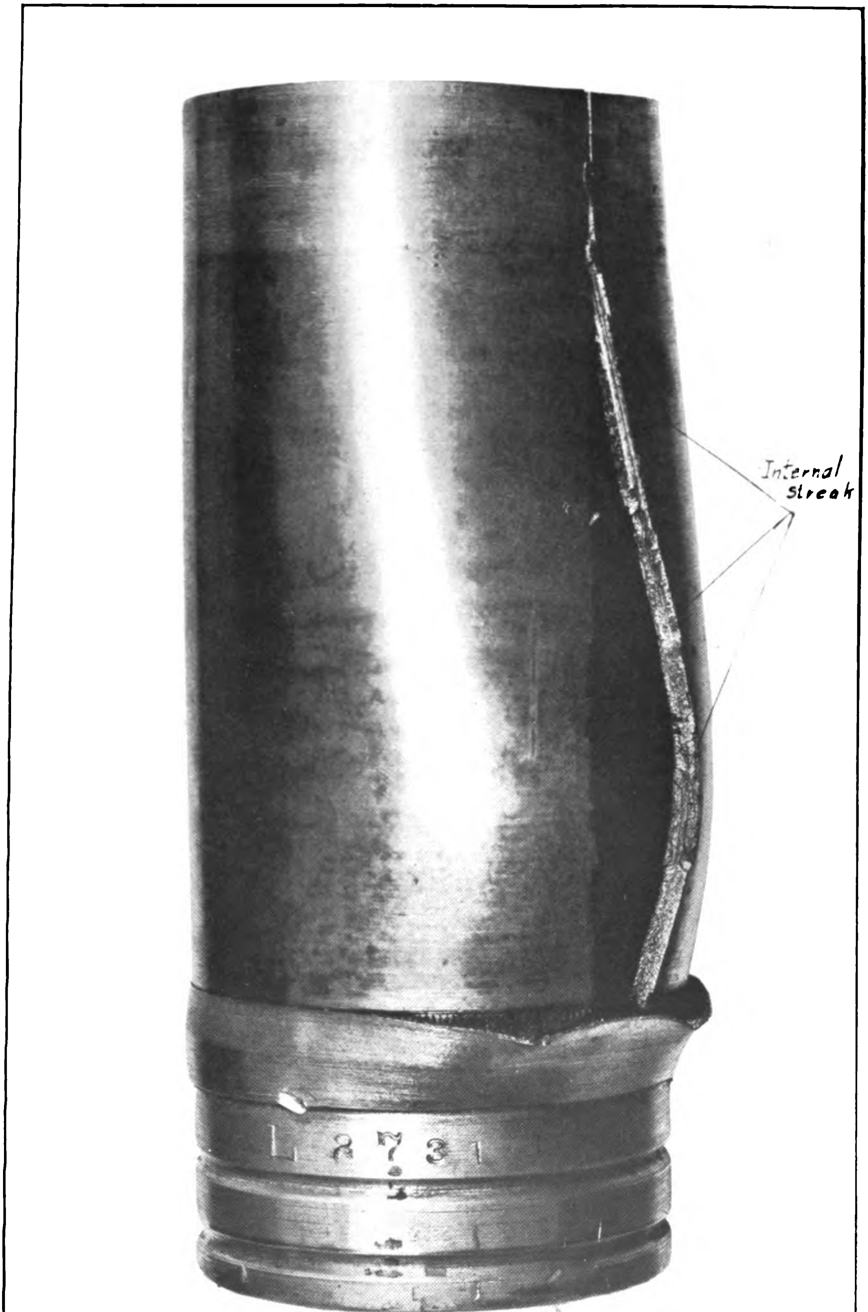
Applied loads.			Exterior diameter of case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	2.92	
3,000	556	4,850	2.925	
5,000	927	8,100	2.925	
10,000	1,854	16,200	2.925	
15,000	2,782	24,300	2.925	
20,000	3,710	32,400	2.93	
25,000	4,640	40,500	2.93	
30,000	5,570	48,650	2.93	
35,000	6,490	56,650	2.93	
40,000	7,420	64,800	2.93	
45,000	8,350	72,900	2.935	
50,000	9,280	81,000	2.935	
55,000	10,200	89,100	2.94+	
60,000	11,120	97,100	2.95	
72,900	13,520	118,000	....	Ultimate strength.

Fractured at longitudinal streak extending the entire length of the reduced section of the case.



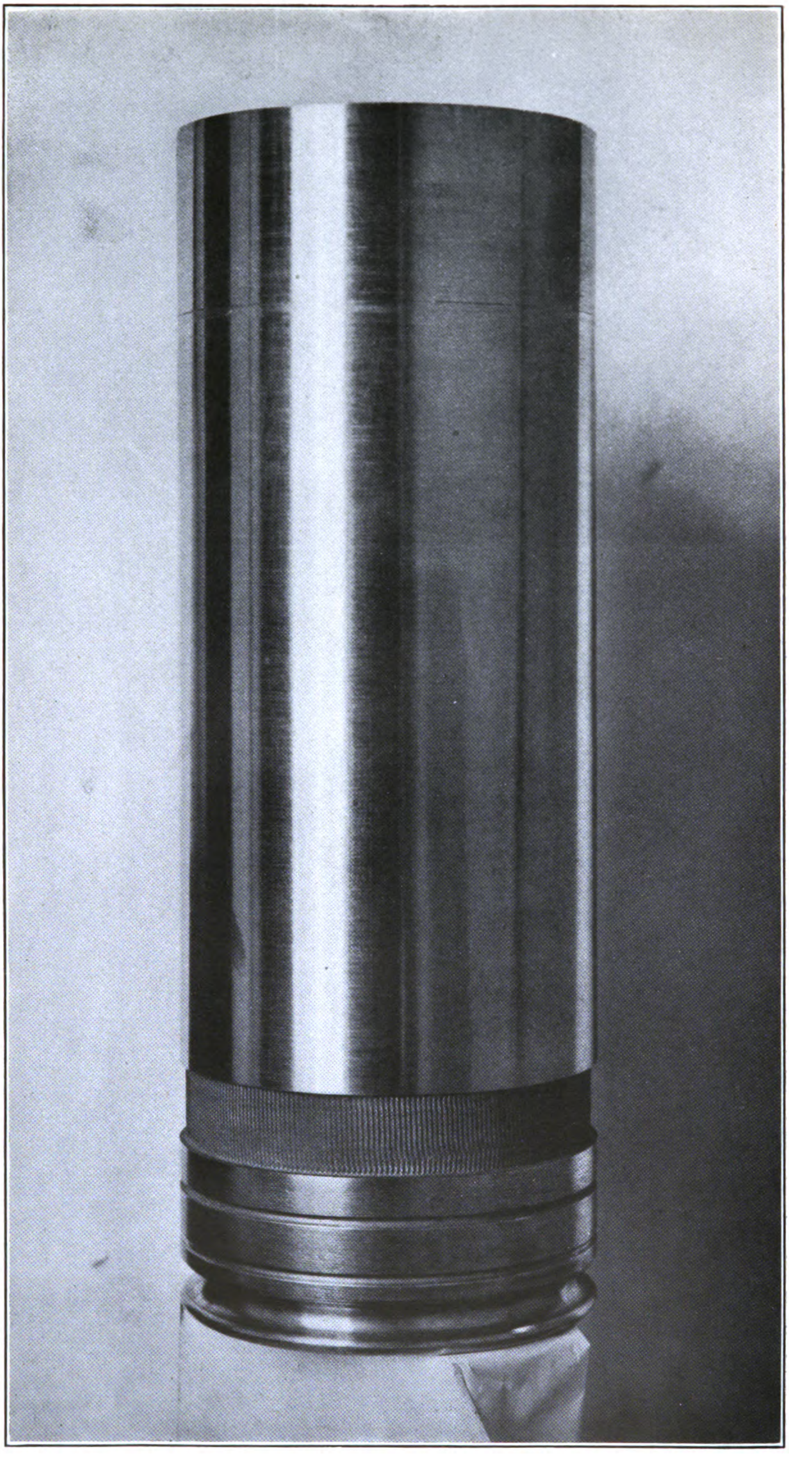
2.95-INCH SHRAPNEL CASE L MANUFACTURED AT FRANKFORD ARSENAL FROM BAR STOCK. UNDER P. O. NO. 2731. POLISHED AND ETCHED WITH IODINE. CASE SHOWS A FEW SHORT BUT QUITE PRONOUNCED STREAKS.

30–1

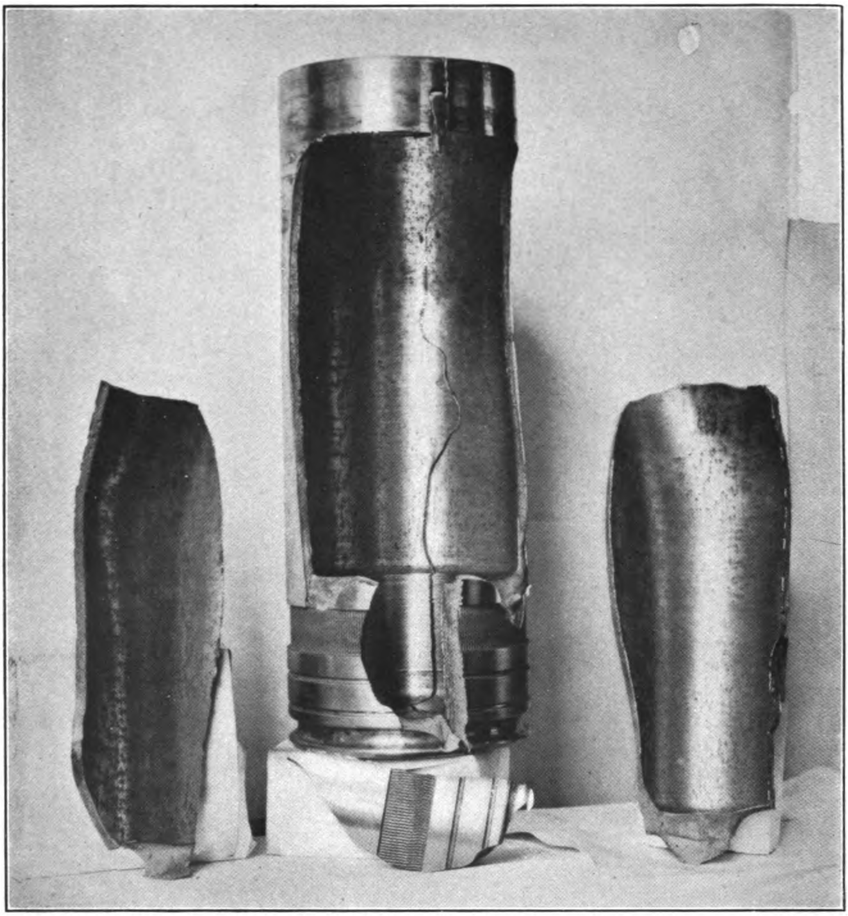


2.95-INCH SHRAPNEL CASE L AFTER FRACTURE. FRACTURE DID NOT OCCUR AT SURFACE STREAK, BUT REVEALED SEVERAL INTERNAL STREAKS.

30-2



4.7-INCH SHRAPNEL CASE MANUFACTURED AT WATERTOWN ARSENAL FROM PURCHASED BAR STOCK. POLISHED AND ETCHED WITH IODINE. NO STREAKS VISIBLE.



4.7-INCH SHRAPNEL CASE AFTER FRACTURE. CASE SHATTERED AS SHOWN. METAL STRONG AND SOMEWHAT BRITTLE. FRACTURES SHOWED NO INTERNAL STREAKS.

HYDROSTATIC TEST OF A 4.7-INCH SHRAPNEL CASE MANUFACTURED AT WATERTOWN ARSENAL FROM BAR STOCK.

It was considered desirable to know how the cases made from bar stock, heat treated at this arsenal, compared with the results shown in the previous report. The fixtures used were exactly the same as before, except that the hydraulic cylinder was bushed to take the 4.7-inch case.

The maximum fiber stress was found to be 197,000 pounds per square inch, compared to 117,000 to 149,700 pounds per square inch for the 6-inch cases, and 122,000 to 163,000 for the 3-inch cases.

Before test the etched case showed no streaks or seams. The dark lines in the photograph are shadows due to light effect only. After testing the fracture was clean with no sign of streaks. Attention is called to the irregular shape of the tear as shown in photograph. With badly streaked metal the fracture usually occurs along an element and follows the streak.

The report of physical test of the metal after heat treatment is attached. The required physical properties were obtained, except the elongation, which was 0.5 per cent low.

This shrapnel case was made from bar stock, which analyzed as follows:

	Per cent.
C	0.50
Ni	3.50
Si	.27
Mn	.69
S	.026
P	.024

The bar as received was 10 inches in diameter and was forged down to 5 inches in diameter. A sample case was made and heat treated by oil quenching at 775° C. and annealed at 400° C. for one-half hour. A longitudinal specimen marked "4 S. C." was taken from this sample case and gave the following physical qualities:

	Required.	Actual.
Elastic limit.....pounds..	100,000	160,000
Tensile strength.....do....	135,000	178,000
Elongation.....per cent..	11.0	10.5
Contraction.....do....	25.0	51.0

The case tested by hydraulic pressure was given exactly the same heat treatment as the sample case.

HYDROSTATIC TEST OF A 4.7-INCH SHRAPNEL CASE MANUFACTURED AT WATERTOWN ARSENAL FROM BAR STOCK.

Case showed no streaks.
Outside diameter of case, 4.68 inches.
Inside diameter of case, 4.28 inches.
Bored out for a length of 9.90 inches.
Depth inside, 12.50 inches.
Length over all, outside, 13.05 inches.
Length from top to top edge of band groove, 10.30 inches.

Case entered testing cylinder 1½ inches, leaving 8.40-inch length of reduced thickness of walls exposed to the interior pressure of the test.

Diameter of piston, 5 inches.
Sectional area, 19.63 square inches.

Applied loads.			Exterior diameter o case (inches).	Remarks.
Total pounds on piston.	Interior pressure (pounds per square inch).	Fiber stress on case (pounds per square inch).		
0	0	0	4.68	
3,000	153	1,640	4.681	
5,000	255	2,720	4.681	
10,000	509	5,450	4.6811	
20,000	1,019	10,900	4.6817	
30,000	1,530	16,375	4.6820	
40,000	2,038	21,800	4.6830	
50,000	2,545	27,200	4.6835	
60,000	3,060	32,750	4.6850	
70,000	3,565	38,150	4.6850	
80,000	4,075	43,600	4.6853	
90,000	4,590	49,100	4.6855	
100,000	5,090	54,500	4.6860	
110,000	5,600	59,900	4.6868	
120,000	6,115	65,500	4.6875	
130,000	6,625	70,900	4.6885	
140,000	7,130	76,200	4.6890	
150,000	7,650	81,900	4.6895	
362,000	18,400	197,000	....	Ultimate strength.

Case flew into four fragments. No streaks visible in fractures.

SHOCK AND TENSILE TESTS OF SHRAPNEL CASE METAL.

1. The following tests were made to obtain information as to the impact and tensile strengths of metal used in shrapnel cases. A comparison is made of specimens taken from forged bar stock and from cases which were formed by punching. Comparison is also made of longitudinal and tangential specimens. By longitudinal and tangential is meant that the specimens were cut out respectively parallel and normal to the direction of forging.

2. The pieces given below were shipped from Frankford Arsenal with the markings as shown:

One piece of bar stock 7 inches long, 3$\frac{1}{16}$ inches diameter, marked "A." This piece is free from seams and cracks, and shrapnel cases taken from it passed the ballistic test.

One piece of bar stock 7 inches long and 2$\frac{1}{16}$ inches diameter, with visible seams, marked "B." The shrapnel cases from this bar failed in the ballistic test.

Several pieces of 3-inch shrapnel cases that broke up in ballistic tests. These pieces were taken from bars which after machining showed fine lines or seams.

Two shrapnel cases marked "2–1220–12" and "5–1220–12," respectively. These shrapnel cases are from lots 2 and 5, respectively, both of which failed in ballistic tests at this arsenal.

Two shrapnel cases marked "Navy" rear of band.

TABLE I.—*Charpy impact tests.*

	No.	Sectional area (square inches.)	Angle.	Foot-pounds.	Foot-pounds per square inch (average).		Brinell hardness (average).		Direction of specimen.
Bar A (free from seams)............	1	0.0707	150.0	4.00	56.6	59.6	255	262	Longitudinal.
	2	.0721	149.5	4.50	62.5		269		
Bar B (seamy).....	1	.0719	147.5	6.60	91.8	80.9	255	255	Do.
	2	.0721	149.0	5.04	70.0		255		
Case No. 2–1220–12..	1	.0719	149.0	5.04	70.1	68.7	241	253	Tangential.
	2	.0655	149.0	5.04	77.0		269		
	3	.0710	149.5	4.50	63.4		262		
	4	.070	149.5	4.50	64.3		241		
Navy case..........	1	.0689	153.0	1.15	16.7	22.9	340	321	Do.
	2	.0718	153.0	1.15	16.0		340		
	3	.0711	152.0	2.10	29.5		302		
	4	.0707	152.0	2.10	29.7		302		
Case No. 5–1220–12..	1	.0723	149.0	5.04	69.7	55.9	302	278	Do.
	2	.0723	151.0	3.05	42.2		255		

All specimens 10 by 10 by 55 millimeters.

3. From the above data it is seen that bar B, which was marked "seamy," gave a greater resistance to shock than bar A, which was free from seams. The cause of this apparently inconsistent result can not be explained. The Navy cases gave the least resistance to shock; the Brinell hardness figures 340 and 302 show that they were the hardest cases of all. With the exception of case B, the resistance to shock varies inversely as the hardness. The fragments of 3-inch cases furnished were too small to obtain test pieces. These were

polished, however, and the micrographs attached indicate that the fine lines or seams referred to were slag streaks. (See Photographs Nos. 1 and 2.)

4. In order to determine whether there was a variation in the specimens taken out longitudinally and tangentially, the following tests were made on bars A and B:

TABLE II.

Specimen.	Elastic limit.	Tensile strength.	Elongation in one inch.	Contraction of area.	Charpy impact (ft. lbs. per sq. in.).	Brinell hardness.	Remarks.	Method of taking specimen.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Per ct.*	*Per ct.*				
A L..	78,000	132,500	23.0	51.9	281.5	290	No seams.	Parallel to direction of rolling.
A T..	79,000	123,000	9.0	9.5	229.7	262	....	Normal to direction of rolling.
B L..	93,000	129,000	30.0	51.9	245.9	255	Seamy....	Parallel to direction of rolling.
B T..	90,500	121,500	14.0	20.5	240.9	248	....	Normal to direction of rolling.

Bar stock from Frankford Arsenal.

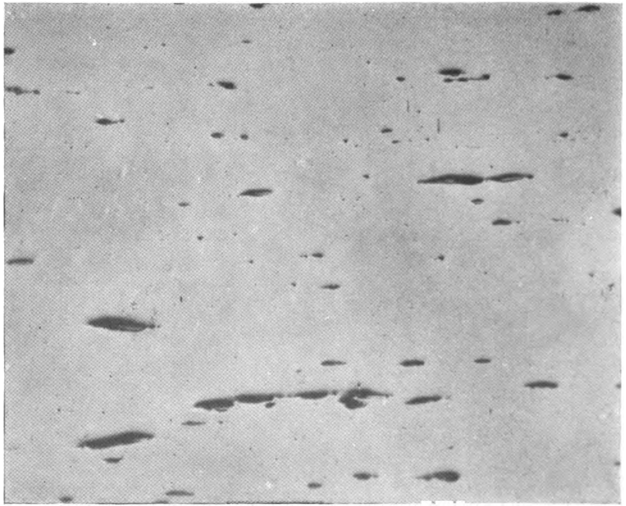
Charpy impact specimens 10 by 10 by 60 millimeters.

The results of the Charpy impact tests above can not be compared with those in Table I, because the span and depth of notch were different. The results are comparable among themselves, however. From the above table we see that the elastic limits are practically the same in each case, but all the other values are less for the tangential specimens, the contraction of area showing the greatest decrease. This would indicate that all test specimens for shrapnel cases should be taken tangentially if possible, as this is the direction in which the stresses are applied in service.

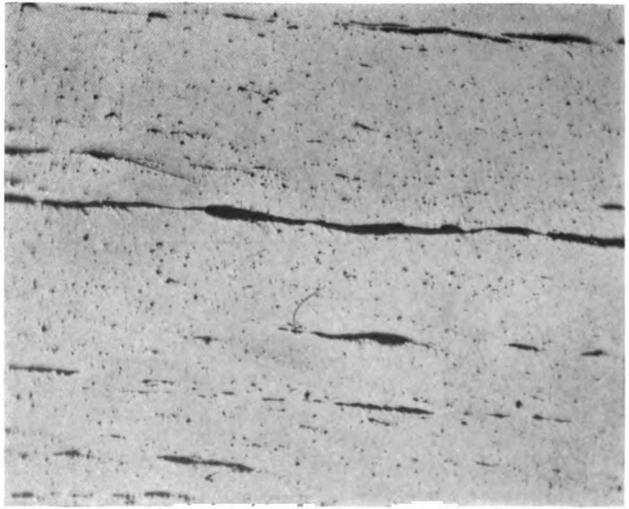
5. In order to continue the investigation further, the following tests were made on the 6-inch, 3-inch, and 2.95-inch cases, which had been tested hydraulically.

TABLE III.—*Physical test data on 6-inch shrapnel cases from hydrostatic tests.*

Shrapnel case.	Specimen No.	Method of taking specimen.	Elastic limit (lbs. per sq. in.).	Tensile strength (lbs. per sq. in.).	Elongation in 2 inches.	Contraction of area.
			Pounds.	*Pounds.*	*Per cent.*	*Per cent.*
6-inch. A..........	A L 6-1	Longitudinal......	116,000	144,000	15.5	40.3
	A L 6-2	.....do............	121,500	150,500	14.5	37.2
	A T 6-1	Tangential.........	111,500	136,500	5.5	9.5
	A T 6-2	.....do............	108,000	137,000	7.0	13.3
6-inch. B..........	B L 6-1	Longitudinal......	111,000	142,500	11.5	34.0
	B L 6-2	.....do............	106,500	138,500	17.0	46.2
	B T 6-1	Tangential.........	87,500	123,000	5.5	5.7
	B T 6-2	.....do............	87,500	121,500	5.0	9.5
6-inch. C..........	C L 6-1	Longitudinal......	100,500	133,000	18.0	57.2
	C L 6-2	.....do............	97,000	130,500	18.0	57.2
	C T 6-1	Tangential........	92,000	124,500	13.0	27.4
	C T 6-2	.....do............	95,500	127,000	12.5	27.4
6-inch. D..........	D L 6-1	Longitudinal......	100,500	137,500	17.5	57.2
	D L 6-2	.....do............	98,500	139,500	14.5	59.8
	D T 6-1	Tangential........	92,500	104,500	2.0	1.8
	D T 6-2	.....do............	....	49,500	10	0



PHOTOGRAPH NO. 1. (X75.)



PHOTOGRAPH NO. 2. (X75.)

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TABLE III.—*Physical test data on 6-inch shrapnel cases from hydrostatic tests*—Continued.

Shrapnel case.	Specimen No.	Hydraulic test (bursting).	Charpy impact (average).		Brinell hardness (average).	
		Pounds per sq. in.	*Ft. lbs. per sq. in.*	*Ft. lbs. per sq. in.*		
6-inch. A..........	A L 6-1	133,100	70.1	109.0	302	294
	A L 6-2		148.0		286	
	A T 6-1		196.0	183.9	286	286
	A T 6-2		171.8		286	
6-inch. B..........	B L 6-1	149,700	262.7	242.0	302	294
	B L 6-2		221.4		286	
	B T 6-1		179.1	187.5	269	265
	B T 6-2		196.0		262	
6-inch. C..........	C L 6-1	134,700	186.6	199.6	277	273
	C L 6-2		212.6		269	
	C T 6-1		162.9	183.3	277	273
	C T 6-2		203.8		269	
6-inch. D..........	D L 6-1	117,000	254.5	271.6	269	278
	D L 6-2		288.8		286	
	D T 6-1		171.8	175.7	269	273
	D T 6-2		179.6		277	

[1] Broke at flaw.

Table III again shows that the tangential specimens are lower in all their physical properties than the longitudinal, the greatest difference being in the contraction of area. The results of the hydraulic tests are shown in the third column of the lower part of the table. With the exception of case A, the impact strengths are consistently less for the tangential specimens. For cases B, C, and D the tangential impact strengths are 187.5, 183.3, and 175.7, while the hydraulic bursting stresses were 149,700, 134,700, and 117,000 pounds, respectively. The hardness numbers for these three were practically the same.

TABLE IV.—*Charpy impact test data on 3-inch and 2.95-inch shrapnel cases from hydrostatic test.*

Shrapnel case.	Specimen No.	Ultimate strength (hydraulic test).	Charpy impact (average).		Brinell hardness (average).	
		Pounds per sq. in.	*Ft. lbs. per sq. in.*	*Ft. lbs. per sq. in.*		
3-inch. A. Forged..............	A T-1	....	208.2	203.6	340	340
	A T-2		199.0		340	
3-inch. B. Forged..............	B T-1	155,300	216.4	229.9	293	293
	B T-2		243.5		293	
3-inch. C. Forged..............	C T-1	153,500	193.7	178.7	321	321
	C T-2		163.7		321	
3-inch. D. Forged..............	D T-1	163,000	193.0	189.3	311	321
	D T-2		185.6		332	
3-inch. E. Forged..............	E T-1	247,000	197.0	165.7	321	303
	E T-2		134.4		286	
3-inch. F. Forged..............	F 1	274,000	163.2	163.2	321	....
3-inch. G. Bar stock............	G T-1	134,400	163.7	158.8	255	255
	G T-2		152.0		255	
3-inch. H. Bar stock............	H T-1	122,000	120.0	138.5	235	235
	H T-2		157.0		235	
3-inch. I. Bar stock............	I T-1	130,300	193.0	174.4	277	282
	I T-2		155.8		286	
3-inch. J. Bar stock............	J T-1	138,100	174.8	151.6	302	302
	J T-2		128.5		302	
2.95-inch. K. Bar stock........	K T-1	126,500	140.9	137.0	255	262
	K T-2		133.1		269	
2.95-inch. L. Bar stock........	L T-1	118,000	59.7	100.3	255	258.6
	L T-2		140.9		262	

All specimens in Table IV were taken from the bases of the fractured 3-inch and 2.95-inch cases. Therefore they are for all practical purposes tangential specimens.

With the exception of 3-inch case I, all cases made from bar stock have a lower impact strength than those made from forgings; this in spite of the fact that the forged cases average harder than those from bar stock. It has been found that, other things being equal, the harder the metal the less is its resistance to shock.

CONCLUSIONS.

1. Specimens for test should be taken in the direction in which the service stress is applied, viz, tangentially.
2. The shock test is not as sensitive as the tensile test.
3. Shrapnel cases made from bar stock are inferior to those made from "forgings."

HARDNESS AND WARPAGE OF SHRAPNEL CASE METAL.

Eight experimental 4.7-inch shrapnel cases were made from a purchased bar, 5-inch diameter. The chemical composition was as follows:

	Per cent.
C	0.50
Ni	3.50
Si	.27
S	.026
P	.024
Mn	.69

This material after annealing at 775° C. for four hours gave the following physical test:

Elastic limit	62,500 lbs. per sq. in.
Tensile strength	100,000 lbs. per sq. in.
Elongation	22.5 per cent.
Contraction	40.3 per cent.
Brinell hardness number	187

After rough machining the cases were heated to a temperature of 775° C., held for a period of two hours, and quenched completely in cottonseed oil. Five cases were then subjected to the Brinell test for hardness, and certain measurements were made to determine degree of warping due to quenching.

Table marked "No. 1" gives data regarding measurements before and after quenching. Table marked "No. 2" gives hardness numbers after quenching. The hardness numbers indicated the metal would be too hard to machine.

Cases were then drawn at 300° C. for a period of 30 minutes. The hardness number taken after this treatment indicated that the material was too hard for machining.

Cases were then drawn at 400° C. for a period of 30 minutes. A physical test was taken from wall of case marked "No. 4" and subjected to test. Result as follows:

Mark, 4 S C.

Elastic limit	160,000 lbs. per sq. in.
Tensile strength	178,000 lbs. per sq. in.
Elongation	10.5 per cent.
Contraction	51.0 per cent.

The hardness numbers of the material after this anneal were as follows:

Case No.	Instrument.	Distances from base (inches).						
		0.70	2.70	4.70	6.70	8.70	10.70	12.70
4	Ball	430	418	418	418	418	387	364
	Shore	70	68	67	65	66	62	60

Cases were measured after this final treatment and table marked "No. 3" gives the measurements.

TABLE No. 1.—*Five shrapnel cases before heat treatment and after oil hardening.*

Case No.	Outside diameters.			Inside diameters ½ inch from top.	Length at ogive on top.
1	Top	4.781	4.7825	3.188	
		4.784	*4.781*	*3.190*	12.228
	Center	4.782	4.781		
		4.783			
	Bottom	4.783	4.7835	3.188	13.260?
		4.785	*4.7815*	*3.190*	
2	Top	4.752	4.7515	3.312	
		4.754	*4.753*	*3.310*	12.2025
	Center	4.752			
		4.759			
	Bottom	4.753	4.7525	3.313	*13.2115*
		4.757	*4.749*	*3.316*	
3	Top	4.7625	4.7635	3.195	
		4.766	*4.7655*	*3.1975*	12.186
	Center	4.7625		3.195	
		4.763			
	Bottom	4.7645	4.7645	*3.197*	*13.208*
		4.765	*4.765*		
4	Top	4.764	4.763	3.192	
		4.768	*4.767*	*3.194*	12.197
	Center	4.764			
		4.765			
	Bottom	4.7645	4.7635	3.193	
		4.7655	*4.7635*	*3.195*	*13.209*
5	Top	4.7505	4.7495	3.312	
		4.7495	*4.7535*	*3.316*	[1] *12.199*
	Center	4.7503			
		4.753			
	Bottom	4.751	4.7495	3.313	
		4.7555	*4.751*	*3.317*	*13.212*

[1] Block vernier end of jaw.

Readings old 6-inch verniers.
Readings *in italics* were taken after hardening.

TABLE NO. 2.—*Hardness numbers of 4.7-inch Watertown Arsenal shrapnel cases.*

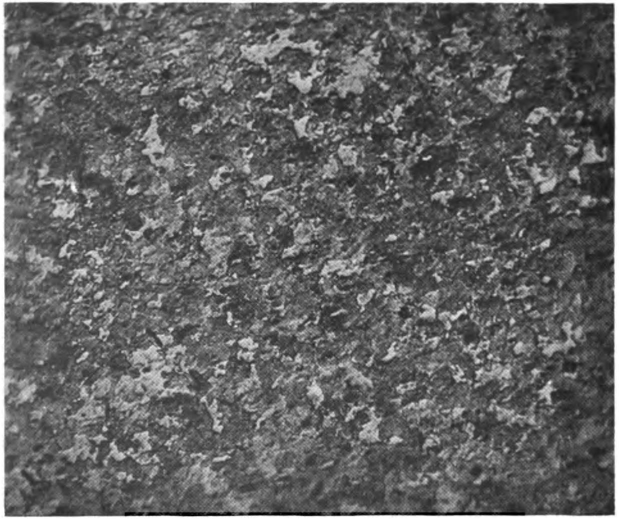
Case No.	Instrument.	Distances from base (inches).						
		0.70	2.70	4.70	6.70	8.70	10.70	12.70
1	Ball	477	477	477	477	477	477	444
	Shore	80	80	80	80	79	76	76
2	Ball	460	477	477	477	460	430	418
	Shore	76	77	76	76	75	71	65
3	Ball	460	477	477	477	460	477	444
	Shore	72	76	76	72	71	71	67
4	Ball	444	444	430	430	418	387	375
	Shore	70	71	71	70	66	65	59
5	Ball	444	444	444	444	430	418	387
	Shore	73	73	72	70	64	64	60

TABLE NO. 3.—*Measurements on 5 shrapnel cases before and after heat treatment.*

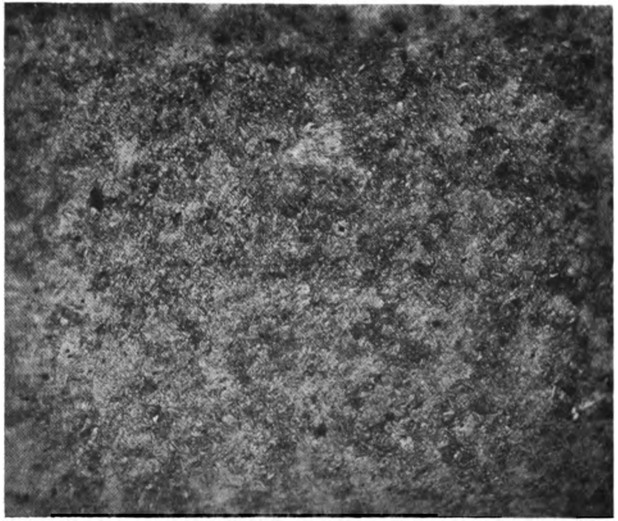
	(1)		(2)		(3)		(4)		(5)	
	Differences from first measurements at—									
	First treatment.	Second treatment.	First treatment.	Second treatment.	First treatment.	Second treatment.	First treatment.	Second treatment.	First treatment.	Second treatment.
Outside diameters:										
At top	+0.002	+0.0025	+0.002	+0.001	+0.0041	+0.002	+0.004	....	−0.001	−0.0015
At center	+ .001	(1)	+ .007	+ .002	+ .0005	− .0015	+ .001	....	+ .0027	+ .0017
At bottom	+ .002	+ .0045	+ .004	+ .0025	+ .0005	− .0015	+ .001	....	+ .0045	+ .002
90° to above:										
At top	− .0015	− .0015	− .002	+ .0015	− .002	+ .0005	+ .004	....	+ .004	+ .0035
At bottom	− .002	(1)	+ .003	− .0035	+ .0015	− .0005	(1)	....	+ .0015	− .0005
Inside diameter at top	+ .002	+ .003	− .002	+ .007	+ .0025	+ .0005	+ .002	....	+ .004	+ .006
	+ .002	+ .006	+ .003	+ .003	+ .002	+ .007	+ .002	....	+ .004	+ .004
Length	+ .032	+ .03	+ .009	+ .009	+ .022	+ .016	+ .012	....	+ .013	+ .0115

[1] Original diameter.

No warping or springing (in length) of any of these cases in either treatment.



ANNEALED AT 775° C., TWO HOURS. (X75.)



AIR CHILLED AT 775° C.; DRAWN ONE-HALF HOUR AT 550° C.; COOLED IN FURNACE. (X75.)

TEST OF STEEL FOR EXPERIMENTAL SHRAPNEL CASE.

An ingot of steel of the following composition—

	Per cent.
C	0.455
Mn	.532
Si	.157
S	.037
P	.016
Ni	3.50
Cr	1.50

was cast in a 6-inch A. P. chill mold, then forged down to 4 inches diameter. Samples of this steel 0.7 inch thick were sent to the laboratory for heat treatment.

The heating and cooling curve shows the critical points to be Ac_1, 725° C., and Ar_1, 405° C.

The following results show the effect of heat treatment:

Specimen No.	Elastic limit.	Tensile strength.	Elongation. in 2 inches.	Contraction of area.	Ball hardness.	Heat treatment.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Per ct.*	*Per ct.*		
SCXF-2	68,500	123,000	20.5	54.6	228	Annealed at 775° C. for 2 hours.
SCXF-2	(1)	(1)	(1)	(1)	555	Air chilled at 775° C. after holding for 1½ hours.
SCXF-2	(1)	(1)	(1)	(1)	444	Drawn at 430° C. one-half hour; cooled in furnace.
SCXF-2	132,000	158,000	6.5	25.0	332	Drawn at 550° C. one-half hour; cooled in furnace.
SCXF-4	66,600	123,200	21.5	54.5	(2)	Longitudinal test after annealing 2 hours at 775° C.
SCXF-5	65,600	121,000	16.0	34.0	(2)	Tangential test after annealing 2 hours at 775° C.
SCXF-6	74,000	131,000	15.5	59.0	241	Air chilled at 775° C.; drawn at 600° C. one-half hour; cooled in furnace.
SCXF-7	134,800	157,100	12.5	50.0	302	Air chilled at 775° C.; drawn one-half hour at 550°C.; cooled in furnace.

[1] Too hard to machine.

[2] Not taken.

The specifications call for the following physical properties:

Elastic limit	100,000 lbs. per sq. in.
Tensile strength	135,000 lbs. per sq. in.
Elongation	11.0 per cent.
Contraction	25.0 per cent.

Attention is called to the fact that all experimental pieces were about the same thickness as the rough finish of the walls of the 4.7-inch shrapnel case, viz, 0.7 inch.

A comparison of specimens taken longitudinally and tangentially seems to indicate that the same ductility can not be obtained across the grain as along the grain.

The micrographs show the annealed condition of the metal and the structure after drawing at 550° C.

RESISTANCE OF ROTATING BANDS.

REPORT OF TEST OF RESISTANCE OF ROTATING BANDS IN 12-INCH MORTAR, MODEL OF 1912.

In order to determine the resistance of several types of rotating bands, the following experiments were made:

A 12-inch mortar, model of 1912 (drawing 62–10–1), was placed between the screws of the 800,000-pound Emery testing machine. Projectiles with different types of bands were forced through the bore of the gun, and the pressure required was weighed on the machine.

ARRANGEMENT OF APPARATUS.

Two general views of the complete arrangement are shown in photographs Nos. 1 and 2. Photograph No. 1 was taken from the straining end of the machine, photograph No. 2 from the weighing end.

The bands were placed on regular 12-inch 700-pound D. P. projectiles. The ogive of each shell was cut off just forward of the bourrelet. The base of the projectile was solid except for a central hole 2 inches in diameter used for centering the forcing bars, which were 9 inches in diameter by 7 feet long. During a test three of these were used end to end connected by means of two bronze collars, which also centered them in the bore. These bars are shown in photographs Nos. 1 and 3.

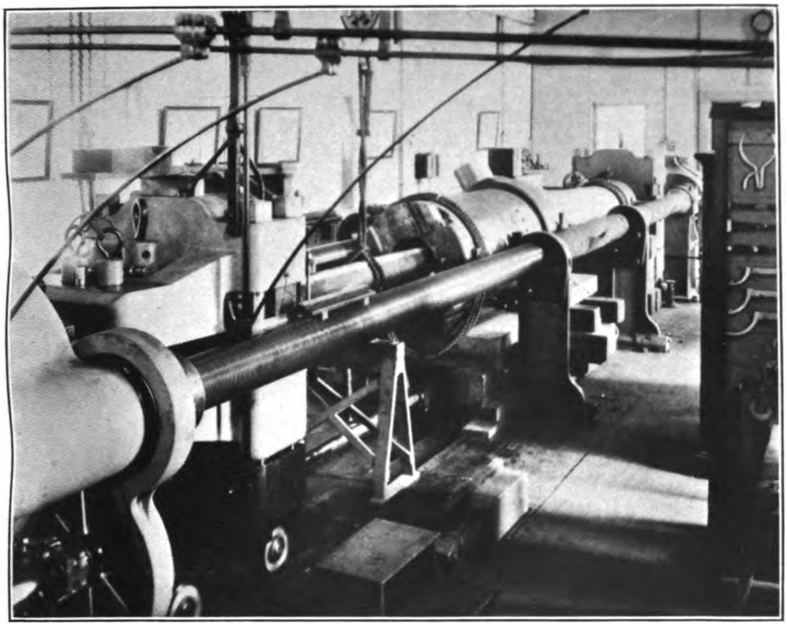
A large roller bearing (see photograph No. 3) was inserted between the forcing bar and the straining head to take care of the turning of the bar and projectile caused by the rifling. The gun itself was mounted on steel rollers to allow of longitudinal motion (see photograph No. 4). The force required to start the gun moving was found to be 400 pounds, which was negligible in comparison with the loads measured.

Between the muzzle of the gun and the weighing head of the testing machine a hollow cylindrical collar was inserted (see photograph No. 5). This transmitted the load from the gun to the weighing head and allowed the removal of the projectile after emerging from the bore.

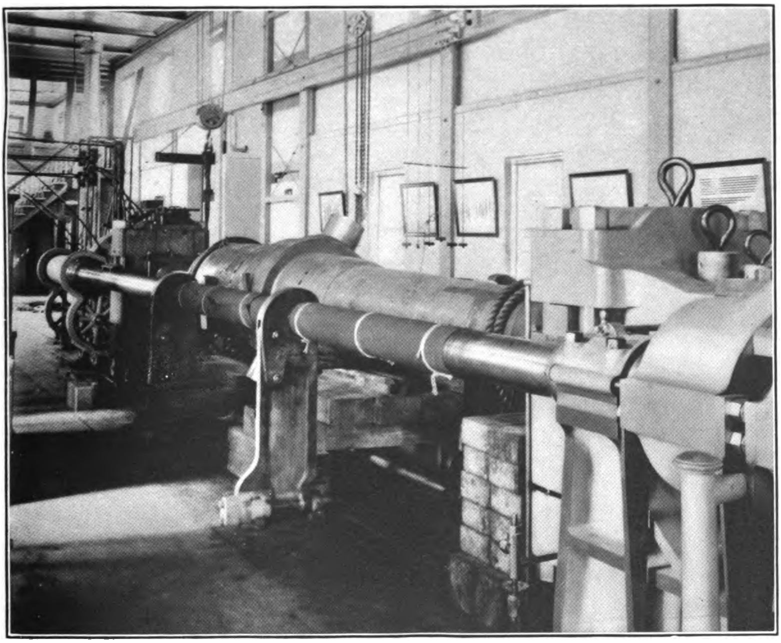
In starting a test the force was applied very slowly, so that the beginning of the load-distance curve could be accurately plotted. Data, photographs, and curves are appended.

DESCRIPTION OF TEST.

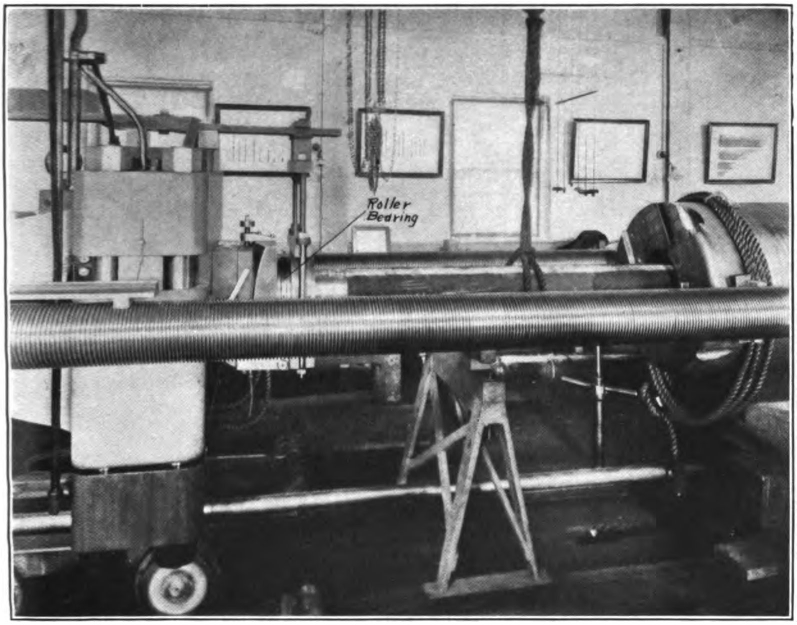
Three different kinds of bands were tested, viz, the old 1¼-inch split band shown on drawing 75–12–1, April 29, 1907, the 2-inch band shown on drawing 75–12–24, and the 1¼-inch band shown on drawing 75–12–1, current date. The broad bands were not tested, as the force required would have exceeded the capacity of the testing machine.



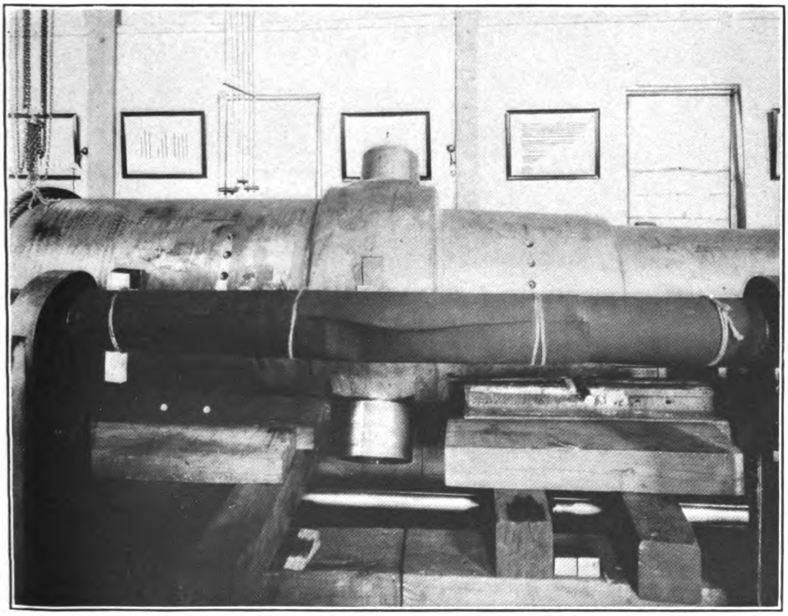
PHOTOGRAPH NO. 1. VIEW OF SET-UP FROM STRAINING END, SHOWING FORCING BAR IN PLACE, REMOVABLE COLLAR IN PLACE AT WEIGHING HEAD, AND STEEL ROLLERS UNDER GUN.



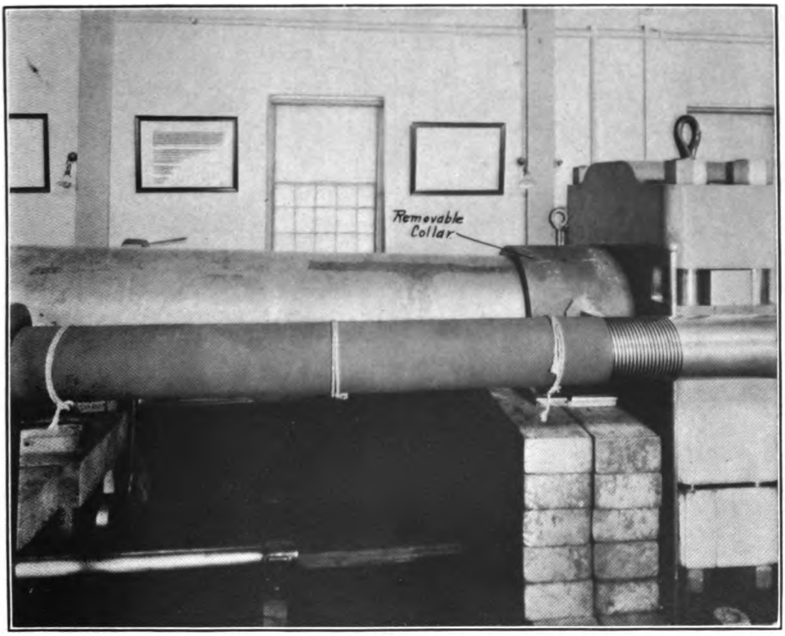
PHOTOGRAPH NO. 2. VIEW OF SET-UP FROM WEIGHING END.



PHOTOGRAPH NO. 3. VIEW OF BREECH END, SHOWING CONNECTION BETWEEN STRAIN HEAD AND FORCING BAR.



PHOTOGRAPH NO. 4. VIEW SHOWING MIDDLE SECTION OF GUN AND STEEL ROLLERS UNDER SAME.



PHOTOGRAPH NO. 5. VIEW OF MUZZLE END, SHOWING WEIGHING HEAD AND REMOVABLE COLLAR.

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Type of b
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1½-inch lar No.
2-inch lar No.
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The regular 1¼-inch continuous band was first forced through the clean gun and gave a maximum pressure of 500,000 pounds, with an average pressure of about 350,000 pounds for the last part of the travel. The second band was the same as the first, but the gun was dry and the lands were fouled with a copper deposit from the first test. The pressures obtained were much higher, probably due to this fouling, the maximum being 672,000 pounds, and the average 450,000 pounds.

The gun was then cleaned with wire and bristle brushes to remove the copper deposit and the bore was lubricated with Keystone grease for the first half of its length. With the bore clean and lubricated, the first 2-inch band was forced through, giving a maximum pressure of 650,000 pounds, with an average of about 450,000 pounds. A similar band (No. 5) was forced through the gun after cleaning with a bristle brush only. This did not remove the copper deposit from the lands, and the pressures obtained—maximum 765,000 pounds, average 550,000 pounds—were considerably higher than with band No. 3.

Band No. 4 was a pure copper split band of the old type. This was hammered cold into its seat on the projectile. The scleroscope reading (15–16) is slightly higher than for the other bands. The gun was cleaned with a bristle brush and the pressures obtained were, maximum 675,000, average 450,000 to 500,000. Band No. 6 was of pure copper similar to No. 4. The gun was cleaned with both wire and bristle brushes, but the accumulation of copper on the lands could not be entirely removed. The pressures obtained—maximum 690,000, average 550,000—were slightly higher than with band No. 4, probably due to the copper deposit.

Summary.

Type of band.	Chemical analysis.	Method of cleaning.	Lubricated or not.	Scleroscope hardness.		Pressure (pounds).	
				Before test.	After test.	Maximum.	Average.
1¼-inch circular band No. 1.	Cu., 97.30; Ni., 2.43; Mn., 0.21.	New, clean gun.	Practically clean; some grease in bottom of grooves.	14	19	499,000	350,000
1¼-inch circular band No. 2.	Same as No. 1..	Bore was fouled from previous test.	Bore dry......	14	19	672,000	450,000
2-inch circular band No. 3.	Cu., 97.27; Ni., 2.48; Mn., 0.21.	Cleaned with wire and bristle brushes.	Bore was slightly lubricated one-half its length.	12	17	650,000	450,000
2-inch circular band No. 5.	Same as No. 3.	Cleaned with bristle brush only.	Bore was lubricated with Keystone grease full length.	12	19	770,000	550,000
1¼-inch split band No. 4.	Cu., 99.7; Ni., none; Mn., none; iron, 0.16.	.....do.........	.....do.........	15	18	675,000	450,000 to 500,000
1¼-inch split band No. 6.	.....do.........	Cleaned with wire and bristle brushes.	.....do.........	16	17	690,000	550,000

By comparing the results in the above table we find that the condition of the bore of the gun has a marked effect on the band resistance. Copper deposited in the bore increases the pressure to a considerable extent. If we compare bands Nos. 1, 3, and 6, the gun being cleaned in each case before the band was tested, we see that the average pressures were 350,000, 450,000, and 550,000, while the maximum pressures were 500,000, 650,000, and 690,000 pounds, respectively; that is, the resistance increases with the width of band and with the amount of cold working. Lubricating the bore appeared to have no effect, as the band fitted the rifling so tightly that the grease was forced ahead.

In all tests except the first the projectile bumped more or less while passing through the bore. This bumping was very marked on bands Nos. 2, 4, and 5, probably due to the copper deposit on lands. Cleaning with a wire brush to remove this deposit decreased the bumping considerably.

CONCLUSIONS.

1. The resistance of the band increases with the width and with the amount of cold working.
2. Copper deposited in the bore increases the resistance to a considerable extent.
3. Lubricating the bore has no apparent effect.

PROJECTILE NO. 1.

1¼-INCH CIRCULAR BAND, AS SHOWN ON DRAWING 75-12-1.

Shore hardness before test, 14.
Shore hardness after test, 19.

Chemical analysis of band.

	Per cent.
Cu	97.30
Ni	2.43
Mn	.21

Appearance of projectile and band after test: Extrusion or lacing of band very regular; bourrelet badly scratched in one place.

Diameter at bottom of grooves in band = diameter across lands in gun. First diameter, 12.012 inches; second diameter at right angles, 12.017 inches.

Remarks: Gun cleaned with bore sponge and bristle brush; some grease remained in bottom of grooves; projectile traversed bore without any bumping.

Projectile No. 1, 1¼-inch circular band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
0	....			
0.1	53,000			
.15	85,000			
.2	109,000			
.25	142,000			
.3	171,000			
.35	205,000			

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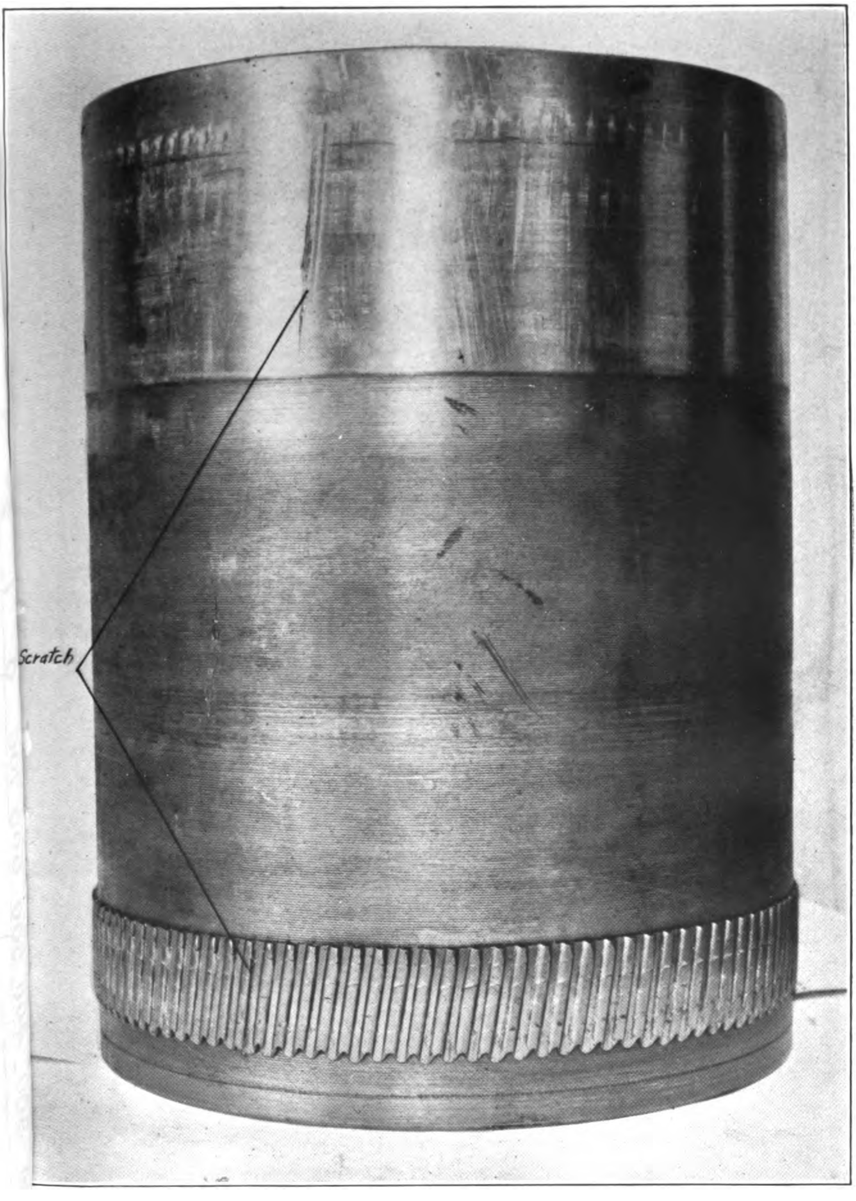

PROJECTILE NO. 1, AFTER TEST; 1¼-INCH CIRCULAR BAND.

Photograph shows uniform extrusion or "lacing" at rear edge of rotating band. Note that at the forward edge of the band the metal only fills the grooves completely on the driving side. Bad scratches on bourrelet and band indicate a rough spot on the rifling.

Di
.4..
.45..
.5...
.55..
.6...
.65..
.7....
.75..
.8...
.85..
.9...
.95..
1.....
1.1....
1.2....
1.25...
1.3....
1.4....
1.5....
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18.5....
19......
19.5....
20......
21......
22......
23......
24......
Stop....
24.5....
25.5....
26.5....
27......
28......
29......
30......
31......
32......
33......
34......
Stop...

Projectile No. 1, 1½-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
0.4	239,000			
.45	275,000			
.5	308,000			
.55	340,000			
.6	369,000			
.65	396,000			
.7	422,000			
.75	434,000			
.8	446,000			
.85	....			
.9	460,000			
.95	464,000			
1	468,000			
1.1	453,000			
1.2	442,000			
1.25	435,000			
1.3	428,000			
1.4	412,000			
1.5	399,000			
1.6	385,000			
1.7	369,000			
1.8	355,000			
1.9	343,000			
2	328,000			
2.1	315,000			
2.3	295,000			
2.5	285,000			
2.7	289,000			
3	298,000			
3.5	322,000			
4	335,000			
4.5	352,000			
5	368,000			
5.5	377,000			
6	382,000			
6.5	388,000			
7	389,000			
7.5	387,000			
8	392,000			
8.5	403,000			
9	409,000			
9.5	426,000			
10	441,000	*H. m. s.*		
10.5	453,000	3 26 00		
11	440,000			
11.5	430,000			
12	426,000	(11 min.)		
12.5	454,000			
13	472,000			
13.5	487,000	3 37 00		
14	484,000			
14.5	492,000			
15	493,000	(14 min.)		
15.5	499,000			
16	496,000			
16.5	478,000	3 51 00		
17	463,000			
18	460,000			
18.5	448,000	3 54 28		
19	433,000			
19.5	416,000			
20	404,000			
21	385,000	3 57 37		
22	373,000			
23	365,000			
24	354,000	4 00 37		
Stop	....	....		
24.5	340,000			
25.5	337,000			
26.5	328,000	4 44 25		
27	324,000			
28	334,000			
29	336,000			
30	338,000			
31	327,000			
32	316,000			
33	322,000			
34	325,000	4 53 30		
Stop	....	....		

Projectile No. 1, 1¼-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
		H. m. s.		
35	318,000	10 49 45		
36	318,000	(23 m. 35 s. time elapsed for 23 inches.)		
37	323,000			
38	325,000			
39	326,000			
40	328,000			
41	332,000			
42	337,000			
43	334,000			
44	332,000			
45	334,000			
46	337,000			
47	340,000			
48	343,000			
49	334,000			
50	329,000			
51	336,000			
52	344,000			
53	343,000			
54				
55	333,000			
56	335,000			
57	338,000			
58	348,000	11 13 10		
Stop				
59	351,000	11 28 20		
60	355,000	(17 m. 26 s. elapsed time for 23 inches.)		
61	348,000			
62	344,000			
63	345,000			
64	345,000			
65	345,000			
66	339,000			
67	336,000			
68	329,000			
69	329,000			
70	329,000			
71	300,000			
72	327,000			
73	328,000			
74	337,000			
74	337,000			
75	333,000			
76	331,000			
77	337,000			
78	343,000			
79	342,000			
80	338,000			
81	340,000			
82	340,000	11 45 46		
Stop				
83				
84	317,000			
85	319,000	1 35 00		
86	319,000	(22 m. 10 s. elapsed time for 21 inches.)		
87	323,000			
88	320,000			
89	315,000			
90	314,000			
91	312,000			
92	314,000			
93	324,000			
94	326,000			
95	324,000			
96	317,000			
97	310,000			
98	301,000			
99	303,000			
100	300,000			
101	295,000			
102	295,000			
103	307,000			
104	311,000			
105	305,000			
106	300,000	1 57 10		
Stop				

Projectile No. 1, 1¼-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.			Time interval (seconds).	Velocity (inches per minute).
		H.	*m.*	*s.*		
107	300,000					
108	300,000	2	26	25		
109	296,000		(10.40 for 10 inches.)			
110	289,000					
111	288,000					
112	286,000					
113	284,000					
114	292,000					
115	299,000					
116	298,000					
117	288,000	2	35	40		
118	286,000	2	37	05		
Stop						
119	285,000	3	32	05		
120	278,000	3	32	58	53	1.13
121	275,000	3	33	34	36	1.67
122	275,000	3	34	05	31	1.93
123	276,000	3	34	37	32	1.87
124	280,000		35	28	51	1.18
125	284,000		36	38	70	.857
126	287,000		37	52	74	.81
127	295,000		38	40	48	1.25
128	298,000		39	21	41	1.46
129	279,000		40	15	54	1.11
130	274,000		41	18	63	.952
131	289,000		42	25	67	.895
132	292,000		43	10	45	1.33
133	300,000		43	50	40	1.50
134	301,000					
135	292,000		45	57	127	.945
136	297,000		47	10	73	.822
137	303,000		48	05	55	1.09
138	296,000		49	15	70	.857
139	300,000		50	46	91	.66
140						
141	305,000		53	22	156	.77
142	306,000		54	32	70	.857
Stop						
143	313,000	4	13	32		
144	316,000	4	14	20	48	1.25
145	305,000		15	06	46	1.30
146	298,000		15	43	37	1.62
147	309,000		16	17	30	2.00
148	312,000		17	06	49	1.22
149	309,000		18	00	54	1.11
150	812,000		18	54	54	1.11
151	320,000		19	18	24	2.50
152	333,000		20	02	44	1.36
153	331,000		20	37	35	1.71
154	301,000		21	22	55	1.09
155	240,000		22	07	45	1.33
156	153,000		22	54	47	1.28
157	0		24	27	99	.606

PROJECTILE NO. 2.

1¼-INCH CIRCULAR BAND, AS SHOWN ON DRAWING 75-12-1.

Shore hardness before test, 14.
Shore hardness after test, 19.

Chemical analysis of band.

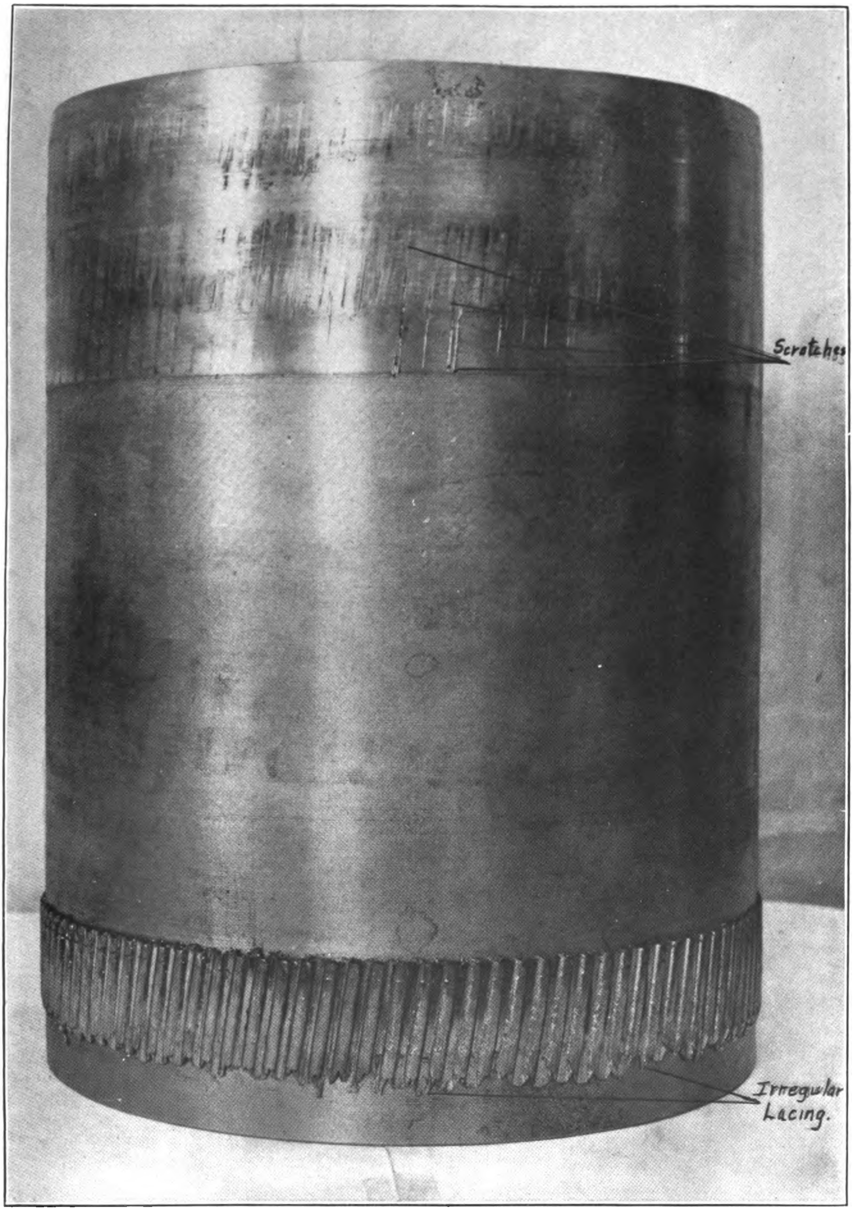
	Per cent.
Cu	97.30
Ni	2.43
Mn	21

Appearance of projectile and band after test: Extrusion "lacing" very irregular and ragged; bourrelet badly scratched several places.

Remarks: Projectile bumped considerably during test; gun n cleaned after testing projectile No. 1, bore dry and copper coate

Projectile No. 2, 1¼-inch circular band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
		M. *s.*		
0.1	320,000	0 00		
.2	370,000	0 54	54	0.111
.3	430,000	1 40	46	.130
.4	474,000	2 38	58	.103
.5	522,000	3 55	77	.078
.6	549,000	5 22	87	.069
.7	554,000	6 59	97	.062
.8	549,000	8 41	102	.059
.9	540,000	10 08	87	.069
1	534,000	11 18	70	.086
1.1	523,000	12 10	52	.115
1.2	508,000	12 56	46	.130
1.3	483,000	13 32	36	.166
1.4	460,000	14 05	33	.182
1.5	439,000	14 27	22	.272
1.6	409,000	14 50	23	.260
1.7	377,000	15 11	21	.286
1.8	346,000	15 30	19	.316
1.9	313,000	15 47	17	.353
2	295,000	16 05	18	.333
2.2	270,000	16 26	21	.57
2.4	282,000	16 44	18	.667
2.6	290,000	17 05	21	.57
2.8	292,000	17 32	27	.444
3	301,000	18 00	28	.428
3.5	324,000	19 18	78	.385
4	348,000	20 37	79	.380
4.5	374,000	22 02	85	.353
5	391,000	23 20	78	.385
5.5	402,000	24 26	66	.455
6	402,000	25 09	43	.698
6.5	402,000	26 11	62	.484
7	408,000	27 13	62	.484
7.5	418,000	28 13	60	.500
8	425,000	29 11	58	.517
8.5	436,000	30 09	58	.517
9	453,000	30 53	44	.682
9.5	468,000	31 29	36	.833
10	478,000	32 23	54	.555
10.5	484,000	33 37	74	.405
11	485,000	34 52	75	.40
11.5	492,000	36 11	79	.38
12	509,000	37 39	88	.34
12.5	524,000	38 45	66	.455
13	536,000	39 20	35	.857
13.5	547,000	40 22	62	.484
14	560,000	41 34	72	.416
14.5	573,000	42 56	82	.366
15	584,000	44 10	74	.405



PROJECTILE NO. 2, AFTER TEST; 1¼-INCH CIRCULAR BAND.

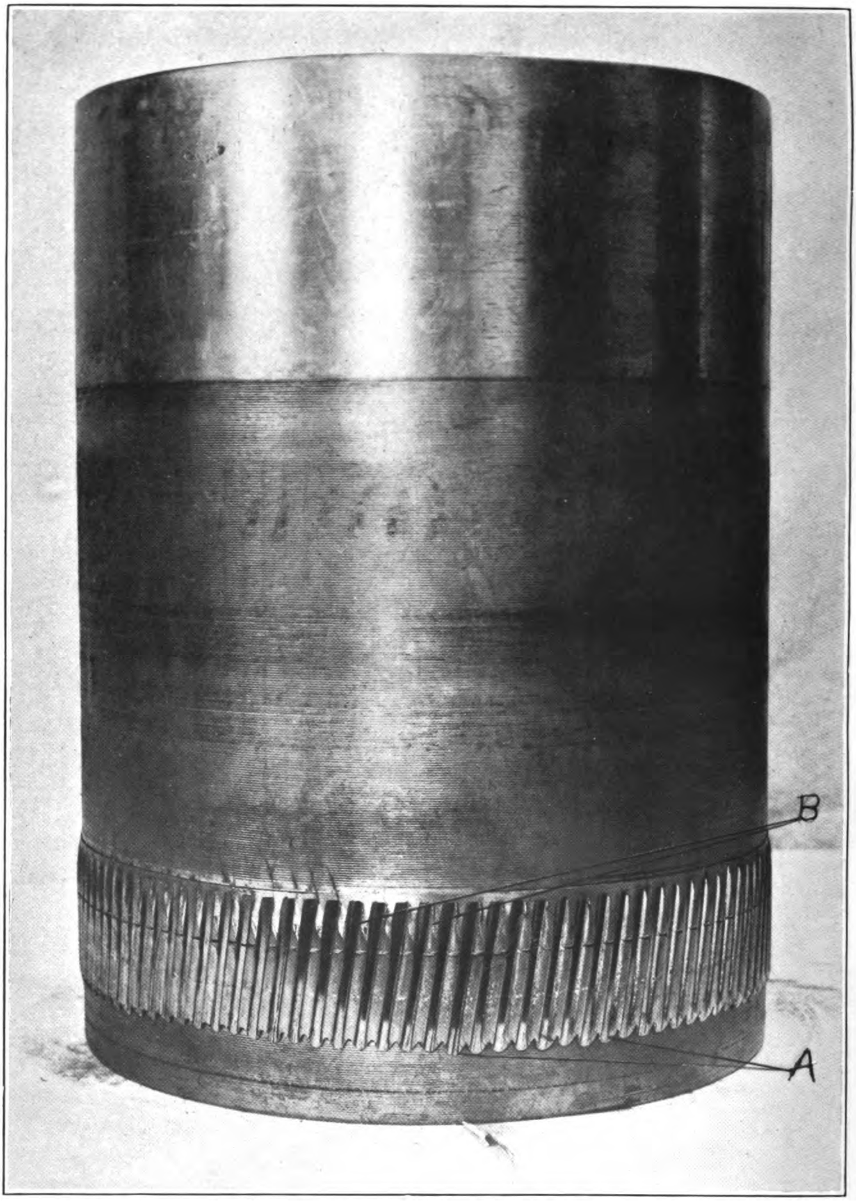
Photograph shows irregular extrusion or "lacing" at rear edge of rotating band. Several scratches on bourrelet visible.

Projectile No. 2, 1¼-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
16	604,000	47	10	180	0.333
17	637,000	48	56	106	.565
18	653,000	58	30	574	1.05
19	654,000	......	......	......	......
20	662,000	0	00	......	......
21	672,000	0	28	28	2.14
22	672,000	0	50	22	2.72
23	665,000	1	13	23	2.61
24	......	......	......	......	......
25	606,000	0	00	......	......
26	600,000		51	51	1.18
27	588,000	1	29	38	1.58
28	573,000	1	55	26	2.30
29	563,000	2	22	27	2.22
30	551,000	2	50	28	2.14
31	536,000	3	18	28	2.14
Stop......	......	......	......	......	......
32	513,000	0	00	......	......
33	510,000		53	53	1.13
34	505,000	1	44	51	1.18
35	499,000	2	53	69	.87
36	500,000	4	22	89	.67
37	490,000	5	31	69	.87
38	500,000	6	20	49	1.22
39	496,000	7	00	40	1.50
40	491,000	7	53	53	1.13
41	498,000	9	21	88	.68
42	502,000	10	55	94	.638
43	488,000	11	54	59	1.02
44	482,000	12	31	37	1.62
45	482,000	13	12	41	1.46
46	491,000	14	36	84	.715
47	494,000	15	42	66	.91
48	498,000	16	34	52	1.15
49	488,000	17	04	30	2.00
50	477,000	17	33	29	2.07
51	482,000	17	58	25	2.40
52	492,000	18	21	23	2.60
53	503.000	18	44	23	2.60
54	497,000	19	04	20	3.00
55	480,000	19	34	20	3.00
Stop......	......	......	......	......	......
56	451,000	0	00	......	......
57	......	......	......	......	......
58	450,000	1	17	77	1.56
59	455,000	......	......	......	......
60	487,000	2	05	48	2.50
61	494,000	2	29	24	2.50
62	......	......	......	......	......
63	495,000	3	14	45	2.66
65	501,000	4	02	48	2.50
67	486,000	5	22	80	1.50
69	471,000	7	45	183	.656
71	485,000	8	52	67	1.79
73	487,000	9	53	61	1.97
75	488,000	11	46	113	1.06
77	480,000	13	18	92	1.305
79	430,000	......	......	......	......
Stop......	......	......	......	......	......
81	478,000	0	00	......	......
83	470,000	1	14	74	1.62
85	452,000	2	13	59	2.04
87	472,000	3	34	81	1.48
89	478,000	5	25	111	1.08
91	463,000	6	23	58	2.07
93	459,000	7	11	48	2.50
95	475,000	7	45	34	3.53
97	456,000	8	15	30	4.00
99	443,000	8	50	35	3.42
101	438,000	9	25	35	3.42
103	470,000	10	53	88	1.36
Stop......	......	......	......	......	......
105	443,000	0	00	0	......
107	442,000		59	59	2.04
109	453,000	1	50	51	2.36
111	442.000	2	41	51	2.36

Projectile No. 2, 1½-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
		M. *s.*		
113	430,000	3 30	49	2.45
115	434,000	4 48	78	1.54
117	428,000	5 51	63	1.90
118	426,000	....	....	....
Stop....	....	....	....	....
120	410,000	0 00	0	....
122	389,000	1 34	94	1.28
124	394,000	....	....	....
126	423,000	4 21	167	1.44
128	413,000	6 24	123	.975
130	380,000	7 23	59	2.04
132	409,000	8 11	48	2.50
134	413,000	8 46	35	3.43
136	415,000	9 26	40	3.00
138	385,000	12 30	184	.65
140	409,000	15 10	160	.75
142	410,000	17 19	129	.93
Stop....	....	....	....	....
144	399,000	0 00	0	....
146	391,000	2 39	159	.755
148	403,000	5 06	147	.816
150	390,000	6 05	59	2.04
151	385,000	7 20	75	.80
152	374,000	8 35	75	.80
153	380,000	9 29	54	1.11
154	377,000	10 02	33	1.82
155	333,000	10 27	25	2.40
156	240,000	10 50	23	2.61
157	110,000	11 16	26	2.30
157.6	0	....	....	....
Stop....	....	....	....	....



PROJECTILE NO. 3, AFTER TEST; 2-INCH CIRCULAR BAND.

Photograph shows (A) the uniform extrusion or "lacing" and (B) how the metal at the forward end of the rotating band fills the grooves on the driving side only.

PROJECTILE NO. 3.

2-INCH CIRCULAR BAND, AS SHOWN ON DRAWING 75-12-24.

Shore hardness before test, 12.
Shore hardness after test, 17.

Chemical analysis of band.

	Per cent.
Cu	97.27
Ni	2.48
Mn	.21

Appearance of projectile and band after test: Extrusion or "lacing" fairly good. Two bad scratches on opposite sides of bourrelet; one was probably present before the test.

Remarks: Projectile traversed first part of bore smoothly, but bumped continually during second half; gun cleaned with wire brush for two-thirds of its length and with bristle brush for its full length, then lubricated for half its length with Keystone grease.

Projectile No. 3, 2-inch circular band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
0.1	60,000				
.2	100,000				
.3	150,000				
.4	210,000				
.5	260,000				
.6	293,000				
.7	....				
.8	338,000				
.9	355,000				
1	372,000				
1.1	388,000				
1.2	397,000				
1.3	394,000				
1.4	399,000				
1.5	406,000				
1.6	411,000				
1.7	401,000				
1.8	388,000				
1.9	372,000				
2	350,000				
2.2	309,000				
2.4	280,000				
2.6	280,000				
2.8	287,000	*M.*	*s.*		
3	294,000	0	20		
3.4	312,000				
3.6	320,000				
3.8	335,000				
4	347,000				
4.5	375,000				
5	398,000	0	00		
5.5	411,000		42	42	0.715
6	418,000	1	26	44	.682
6.5	427,000	1	58	32	.938
7	430,000	2	18	20	1.50
7.5	436,000	2	37	19	1.58
8	455,000	2	57	20	1.50
8.5	466,000	3	19	22	1.36
9	482,000	3	54	35	.857
9.5	501,000	4	42	48	.625
10	511,000	5	31	49	.613
10.5	518,000	6	24	53	.566
11	511,000	7	18	54	.555
11.5	501,000	8	03	45	.666
12	508,000	8	27	24	1.25
12.5	528,000	8	52	25	1.20
13	530,000	9	17	25	1.20

Projectile No. 3, 2-inch circular band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
14	552,000	10	32	75	0.80
15	559,000	11	42	70	.857
16	574,000	12	44	62	.967
17	585,000	13	27	43	1.39
18	595,000	14	20	53	1.13
19	603,000	15	49	89	.674
20	610,000	17	25	96	.625
21	615,000	18	27	62	.967
22	621,000	19	15	48	1.25
23	629,000	20	44	89	.674
24	628,000	22	19	95	.631
Stop...	....	....	....	....	....
25	607,000	0	00	0	....
26	609,000	1	20	80	.75
27	608,000	2	07	47	1.28
28	611,000	2	43	36	1.67
29	621,000	3	18	35	1.71
30	612,000	4	18	60	1.00
31	607,000	5	15	57	1.05
32	626,000	6	05	50	1.20
33	636,000	6	36	31	1.93
34	626,000	7	06	30	2.00
Stop...	....	....	....	....	....
35	583,000	0	00	0	....
36	598,000		47	47	1.28
37	606,000	....	....	....	....
38	630,000	0	00	0	....
39	634,000		28	28	2.14
40	633,000		57	29	2.07
41	640,000	1	25	28	2.14
42	649,000	1	56	31	1.93
43	641,000	2	42	46	1.30
44	632,000	3	26	44	1.36
45	635,000	4	03	37	1.62
46	637,000	4	31	28	2.14
47	645,000	4	59	28	2.14
48	650,000	5	27	28	2.14
49	642,000	5	55	28	2.14
50	630,000	6	26	31	1.93
51	632,000	7	11	45	1.33
52	645,000	7	54	43	1.395
53	....	....	....	....	....
54	566,000	9	01	67	1.79
55	525,000	9	25	24	2.50
56	532,000	9	48	16	3.75
57	530,000	10	07	26	2.30
58	540,000	10	21	14	4.28
Stop...	....	....	....	....	....
59	545,000	0	00	0	....
60	582,000		44	44	1.36
61	613,000	1	43	59	1.02
62	589,000	2	46	63	.952
63	565,000	3	04	18	3.33
64	520,000	3	27	23	2.61
65	500,000	3	40	13	4.61
66	480,000	3	56	16	3.75
67	484,000	4	29	33	1.82
68	485,000	5	18	49	1.22
69	514,000	6	52	94	.64
70	543,000	8	24	92	.652
71	569,000	9	57	93	.645
72	576,000	10	43	46	1.30
73	470,000	11	42	59	1.02
74	475,000	13	39	117	.513
75	455,000	14	27	48	1.25
76	460,000	15	11	44	1.36
77	460,000	17	11	120	.50
78	480,000	18	52	101	.594
79	482,000	19	50	58	1.03
80	506,000	20	33	43	1.395
81	534,000	21	15	42	1.43
82	500,000	....	....	....	....
Stop...	....	....	....	....	....
83	460,000	0	00	....	....
84	473,000	1	50	110	.545
85	....	....	....	....	....
86	470,000	3	13	83	1.45

Projectile No. 3, 2-inch circular band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
87	502,000	4	14	61	0.984
88	522,000	5	28	74	.81
89	....	6	41	73	.822
90	....	6	59	18	3.33
91	450,000	7	11	12	5.00
92	455,000	7	43	32	1.87
93	450,000	8	18	35	1.76
94	450,000	8	35	17	3.53
95	450,000	9	13	38	1.58
96	460,000	10	05	52	1.15
97	462,000	10	30	25	2.4
98	462,000	10	42	12	5.0
99	470,000	11	07	24	2.5
100	470,000	11	18	12	5.0
101	465,000	11	34	16	3.75
102	465,000	12	06	32	1.875
103	470,000	13	10	64	.938
104	480,000	14	31	81	.74
105	470,000	15	48	77	.78
106	475,000	16	45	57	1.05
Stop...	....	....	....	....	....
107	475,000	0	00	0	....
108	475,000		58	58	1.035
109	430,000	1	47	49	1.22
110	415,000	2	59	72	.834
111	434,000	4	05	66	.91
112	445,000	4	48	43	1.395
113	410,000	0	00	0	....
114	431,000	1	12	72	.834
115	438,000	2	02	50	1.20
116	455,000	2	50	48	1.25
117	458,000	3	35	45	1.33
118	460,000	4	27	52	1.15
Stop...	....	....	....	....	....
119	465,000	0	00	0	....
120	....	....	....	....	....
121	465,000	1	21	81	1.48
122	460,000	2	01	40	1.50
123	455,000	3	02	61	.984
124	455,000	3	26	24	2.50
125	455,000	3	59	33	1.82
126	455,000	4	37	38	1.58
127	455,000	5	35	58	1.03
128	460,000	6	48	73	.822
129	450,000	7	32	44	1.36
130	450,000	7	57	25	2.40
131	450,000	8	14	17	3.52
132	455,000	8	38	24	2.50
133	450,000	8	55	17	3.52
134	458,000	9	23	28	2.14
135	450,000	10	12	49	1.22
136	435,000	11	13	61	.984
137	445,000	12	16	63	.952
138	450,000	12	59	43	1.395
139	445,000	13	51	52	1.15
140	415,000	15	32	101	.594
141	420,000	16	42	70	.858
142	430,000	17	52	70	.858
Stop...	....	....	....	....	....
143	395,000	0	00	0	....
144	395,000	1	28	88	.682
145	395,000	2	08	40	1.50
146	395,000	2	47	39	1.54
147	405,000	3	49	62	.97
148	395,000	5	16	27	2.22
149	392,000	6	25	69	.87
150	415,000	7	15	50	1.20
151	425,000	7	55	40	1.50
152	425,000	8	42	47	1.28
153	425,000	9	49	67	.895
154	435,000	10	32	43	1.395
155	350,000	11	02	30	2.00
156	250,000	11	43	41	1.46
157	100,000	12	17	34	1.76
158	0	....	....	....	....

PROJECTILE NO. 4.

1½-INCH SPLIT BAND, AS SHOWN ON DRAWING 75-12-1.

Shore hardness before test, 15.
Shore hardness after test, 18.

Chemical analysis of band.

	Per cent.
Cu	99.72
Ni	None.
Mn	None.
Fe	0.16

Appearance of projectile and band after test: Extrusion or "lacing" was very uniform; bourrelet of projectile was badly scratched in three places.

Diameter at bottom of grooves in band equals diameter across lands in gun; diameter, 12.039 inches.

Remarks: Projectile traversed first half of bore smoothly but bumped badly and continually during the last half of bore; bore cleaned with bristle brush and lubricated whole length with Keystone grease.

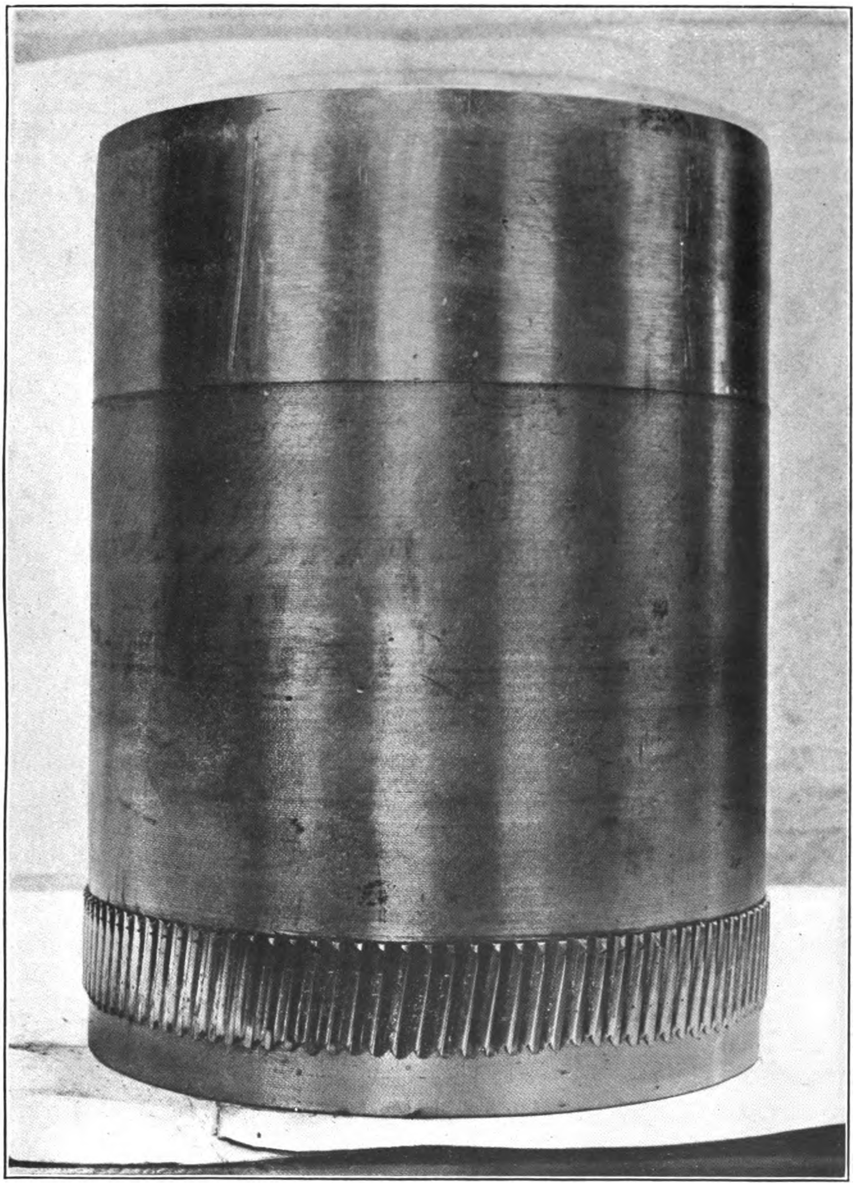
Projectile No. 4, 1½-inch split band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time. *M. s.*	Time interval (seconds)	Velocity (inches per minute).
1	550,000			
1.2	510,000			
1.6	455,000			
1.8	420,000			
2	370,000			
2.2	330,000			
2.4	310,000			
2.6	316,000			
2.8	325,000			
3	340,000	0 00		
3.2	355,000	24	24	
3.4	366,000	52	28	
3.6	380,000	1 56	34	
3.8	399,000	2 02	36	
4	410,000	2 19	17	
4.5	435,000	3 11	52	
5	452,000	4 03	52	
5.5	456,000	4 46	43	
6	459,000	5 24	38	
6.5	455,000	5 49	25	
7	453,000	6 15	26	
7.5	458,000	6 38	23	
8	479,000	7 32	54	
8.5	494,000	8 34	62	
9	520,000	9 41	67	
9.5	543,000	10 50	69	
10	559,000	12 03	73	
10.5	565,000	12 56	53	
11	555,000	13 13	17	
11.5	544,000	13 51	38	
12	547,000	14 30	39	
13	582,000	15 44	74	
14	603,000	16 59	75	
15	599,000	17 34	35	
16	619,000	18 11	37	
17	643,000	19 07	56	
18	675,000	20 37	90	
19	674,000	22 20	103	
20	657,000	23 15	55	
21	642,000	23 56	41	
22	622,000	25 03	67	
23	586,000	26 19	76	
24	555,000	27 34	75	
Stop				

i
i

L

b
c
g



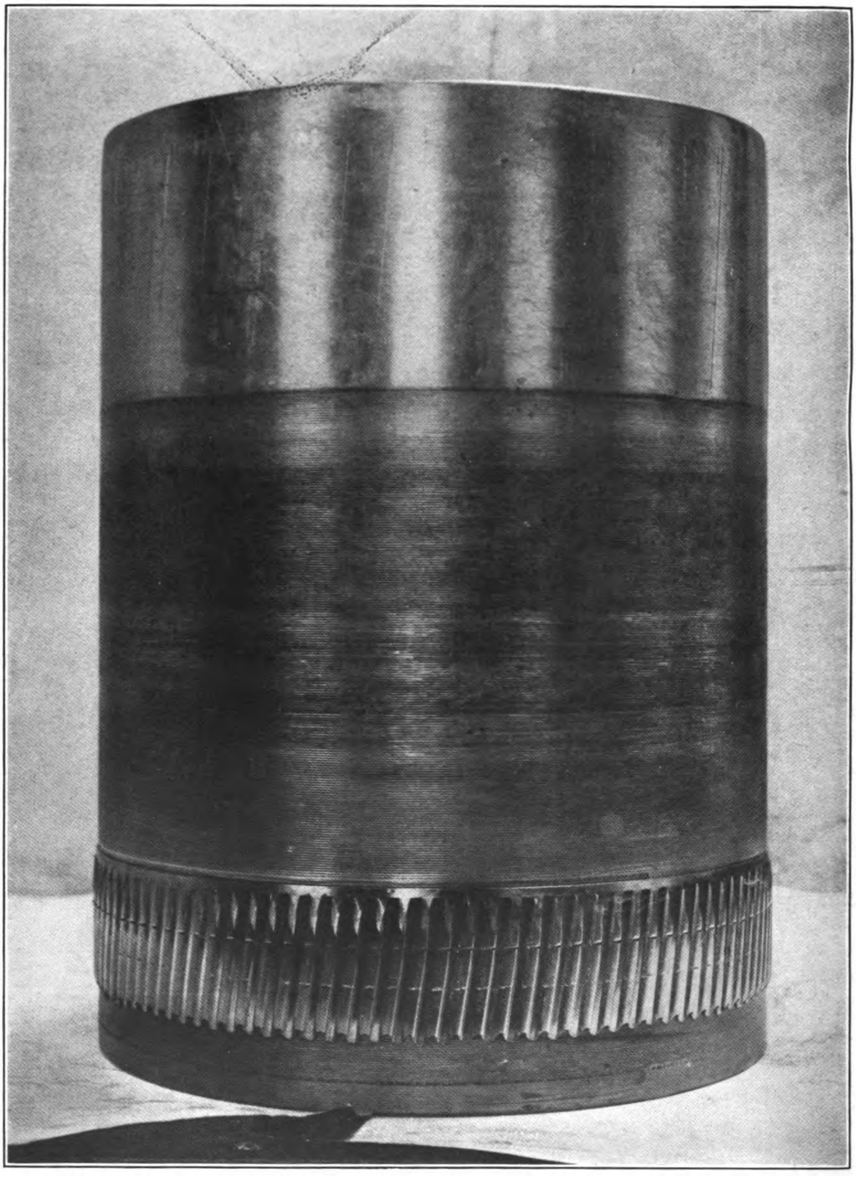
PROJECTILE NO. 4, AFTER TEST; 1½-INCH SPLIT BAND.

Projectile No. 4, 1¼-inch split band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
25	515,000	0	00	0	
26	495,000	1	18	78	
27	484,000	2	15	57	
28	480,000	2	55	40	1.50
29	482,000	4	00	65	.923
30	489,000	5	14	74	.810
31	487,000	6	12	58	1.03
32	498,000	6	49	37	1.62
33	500,000	7	18	29	2.07
34	519,000	8	08	50	1.20
Stop...					
35	511,000	0	00	0	
36	526,000	1	03	63	.952
37	517,000	1	57	54	1.11
38	531,000	3	07	70	.857
39	548,000	4	52	105	.571
40	547,000	6	14	82	.732
41	551,000	7	16	62	.967
42	559,000	8	13	57	1.05
43	560,000	9	23	70	.857
44	559,000	10	31	68	.882
45	562,000	11	27	56	1.07
46	566,000	12	14	47	1.28
47	576,000	13	19	65	.923
48	582,000	14	35	76	.79
49	578,000	15	52	77	.78
50	563,000	16	49	57	1.05
51	568,000	18	00	71	.847
52	595,000	19	30	90	.667
53	590,000	21	05	95	.632
54	514,000	22	00	55	1.09
55	527,000	23	32	92	.652
56	532,000	25	03	91	.66
57	543,000	26	40	97	.619
58	549,000	27	56	76	.790
Stop...					
59	559,000	0	00	0	
60	577,000	1	53	113	.530
61	588,000	3	35	102	.589
62	600,000	5	26	111	.54
63					
64	593,000	8	27	181	.331
65	590,000	9	02	35	1.71
66	590,000	9	57	55	1.09
67	597,000	11	23	86	.699
68	562,000	12	42	79	.76
69	555,000	13	49	67	.895
70	569,000	14	54	65	.924
71	582,000	16	17	83	.723
72	596,000	17	43	86	.698
73	535,000	18	45	62	.968
74	505,000	19	26	41	1.41
75	500,000	20	25	59	1.02
76	507,000	21	43	78	.77
77	550,000	22	02	19	3.16
78	555,000				
79	558,000	24	50	168	.357
80	570,000	26	17	87	.69
81	540,000	27	23	66	.91
82	480,000	28	36	73	.822
Stop...					
83	460,000	0	00	0	
84	455,000	1	05	65	.924
85	460,000	2	45	100	.60
86	509,000	3	39	54	1.11
87	537,000	4	01	22	2.73
88	544,000	5	06	65	.924
89	500,000	5	50	44	1.36
90	440,000	6	37	47	1.28
91	460,000	8	11	94	.639
92	450,000	9	21	70	.857
93	465,000	10	25	64	.938
94	500,000	11	06	41	1.46
95	540,000	11	48	42	1.43
96	465,000	12	23	35	1.71
97	455,000	13	19	36	1.67
98	460,000	14	15	56	1.07

Projectile No. 4, 1½-inch split band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
99	490,000	15	03	48	1.25
100	550,000	15	52	49	1.22
101	470,000	16	45	53	1.13
102	435,000	17	22	37	1.62
Stop...	....	.....	.....	....	....
103	455,000	0	00	0	
104	470,000		56	56	1.07
105	455,000	1	52	56	1.07
106	450,000	2	54	62	.968
Stop...	....	.....	.....	....	....
107	480,000	0	00	0	
108	480,000	1	09	69	.87
109	480,000	1	56	47	1.28
110	475,000	2	25	29	2.06
111	470,000	2	54	29	2.06
112	470,000	.....	.....	....	....
113	470,000	4	21	87	.69
114	470,000	5	16	55	1.09
115	470,000	6	11	55	1.09
116	470,000	6	54	43	1.395
117	470,000	7	24	30	2.00
118	465,000	8	09	45	1.333
Stop...	....	.....	.....	....	....
119	450,000	0	00	0	
120	460,000	1	11	71	.845
121	450,000	1	58	47	1.28
122	455,000	3	15	77	.78
123	455,000	4	47	92	.652
124	450,000	5	55	68	.883
125	455,000	6	48	53	1.13
126	450,000	7	30	42	1.43
127	465,000	8	28	58	1.03
128	460,000	9	40	72	.834
129	....	.....	.....	....	....
130	445,000	11	01	81	1.48
131	445,000	11	36	35	1.71
132	455,000	12	08	32	1.87
133	455,000	12	55	47	1.28
134	445,000	14	00	65	.924
135	440,000	14	57	57	1.05
136	435,000	15	38	41	1.46
137	440,000	16	11	33	1.82
138	435,000	16	53	42	1.43
139	435,000	18	33	100	.60
140	435,000	20	08	95	.63
141	430,000	21	03	55	1.09
142	435,000	21	34	31	1.93
Stop...	....	.....	.....	....	....
143	425,000	0	00	0	
144	440,000	1	06	66	.91
145	445,000	2	00	54	1.11
146	440,000	3	27	87	.69
147	435,000	5	11	104	.577
148	440,000	6	46	95	.631
149	440,000	8	23	97	.619
150	435,000	9	50	87	.69
151	435,000	11	10	80	.75
152	435,000	12	11	61	.985
153	435,000	12	43	32	1.87
154	430,000	13	18	35	1.71
155	380,000	13	55	37	1.62
156	300,000	14	42	47	1.28
157	160,000	15	25	43	1.39
158	....	.....	.....	....	....



PROJECTILE NO. 5, AFTER TEST; 2-INCH CIRCULAR BAND.

PROJECTILE NO. 5.

2-INCH CIRCULAR BAND, AS SHOWN ON DRAWING 75-12-1.

Shore hardness before test, 12.
Shore hardness after test, 19.

Chemical analysis of band.

	Per cent.
Cu	97.27
Ni	2.48
Mn	.21

Appearance of projectile and band after test: Extrusion or "lacing" very nearly perfect; bourrelet of projectile was scratched in three or four places.

Remarks: Projectile bumped badly for nearly the whole length of bore; bore cleaned with bristle brush and lubricated whole length with Keystone grease.

Projectile No. 5, 2-inch band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
0.1	25,000	0	00		
.3	77,000		42	42	0.286
.5	170,000	1	23	41	.293
.7	245,000	2	24	61	.197
1	320,000	4	15	111	.162
1.3	378,000	5	34	79	.228
1.6	369,000	6	39	65	.277
2	395,000	7	54	75	.32
2.5	365,000	9	01	67	.448
3	427,000	9	42	41	.732
3.5	483,000	10	49	67	.448
4	537,000	12	46	117	.256
4.5	583,000	15	30	164	.183
5	623,000	17	43	133	.226
5.5	638,000	19	10	87	.345
6	655,000	20	15	65	.461
6.5	656,000	20	37	22	1.365
7	658,000	20	59	22	1.365
7.5	672,000	21	21	22	1.365
8	685,000	22	38	77	.39
8.5	750,000				
9					
9.5	660,000			377	.398
10	650,000				
11	640,000	28	55		
12	630,000	29	16	21	2.86
13	670,000	29	38	22	2.73
14	700,000	30	05	27	2.22
15	700,000	30	30	25	2.4
16	730,000				
17	740,000	32	14	104	1.15
18	770,000	32	43	29	2.07
20	750,000	33	45	62	1.94
21	620,000	0	00		
22	600,000	0	00		
23	607,000	0	39	39	1.54
24	590,000	1	04	25	2.4
Stop...					
25	532,000	0	00		
26	513,000	0	58	58	1.035
27	502,000	1	43	45	1.33
28	497,000	2	18	35	1.71
29	512,000	2	52	34	1.76
30	521,000	3	30	38	1.58
31	529,000	4	18	48	1.25
32	553,000	5	08	50	1.20
33	577,000	5	54	46	1.30
34	571,000	6	32	38	1.58
Stop...					

Projectile No. 5, 2-inch band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
35	546,000	0	00	....	....
36	564,000	1	01	61	0.985
37	584,000	2	03	62	.968
38	620,000	3	42	99	.605
39	638,000	5	25	103	.583
40	652,000	7	15	110	.545
41	652,000	8	22	67	.895
42	610,000	9	46	84	.715
43	550,000	10	35	49	1.22
44	550,000	11	09	44	1.36
45	560,000	11	50	41	1.46
46	560,000	12	43	53	1.13
47	565,000	13	53	70	....
48	575,000	14	46	53	1.13
49	565,000	15	34	48	1.25
50	555,000	16	19	45	1.33
51	570,000	17	14	55	1.09
52	575,000	18	01	47	1.28
53	560,000	18	29	28	2.14
54	560,000	19	05	36	1.67
55	555,000	19	50	45	1.33
56	555,000	20	51	61	.985
57	560,000	21	41	50	1.20
58	565,000.	22	34	53	1.13
Stop...	....	....		....	....
59	550,000	0	00	....	....
60	575,000	0	59	59	1.017
61	565,000	1	41	42	1.43
62	565,000	2	11	30	2.00
63	565,000	3	15	64	.938
64	565,000	4	10	55	1.09
65	555,000	4	54	44	1.36
66	555,000	5	28	34	1.76
67	570,000	5	54	26	2.31
68	560,000	6	34	40	1.50
69	565,000	7	12	38	1.58
70	....	....		....	....
71	575,000	9	05	113	1.06
72	570,000	9	48	43	1.395
73	565,000	10	20	32	....
74	560,000	10	56	36	1.67
75	565,000	11	44	48	1.25
76	560,000	12	51	67	.895
77	570,000	14	04	73	.822
78	570,000	14	43	39	1.54
79	585,000	15	01	18	3.34
80	590,000	15	19	18	3.34
81	590,000	15	35	16	3.75
82	600,000	15	51	16	3.75
Stop...	....	....		....	....
83	555,000	0	00	....	....
84	555,000	0	50	50	1.20
85	560,000	1	36	46	1.305
86	575,000	2	51	75	.80
87	580,000	3	54	63	.953
88	....	....		....	....
89	585,000	5	25	91	.66
90	570,000	5	56	31	1.935
91	575,000	6	28	32	1.875
92	560,000	7	36	68	.882
93	545,000	8	35	59	1.017
94	570,000	9	06	31	1.935
95	570,000	9	30	24	2.50
96	570,000	10	33	63	.953
97	565,000	11	19	46	1.305
98	....	....		....	....
99	585,000	12	24	65	.924
100	500,000	0	00	....	....
101	....	....		....	....
102	600,000	1	03	63	1.905
103	600,000	1	18	15	4.00
104	650,000	1	40	22	2.725
105	....	2	04	24	2.50
106	650,000	2	23	19	3.16
Stop...	....	....		....	....

Projectile No. 5, 2-inch band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.	Time interval (seconds).	Velocity (inches per minute).
		M. *s.*		
107	620,000	0 00	....	....
108	630,000	0 32	32	1.875
109	640,000	0 58	26	2.30
110	635,000	1 24	26	2.30
111	630,000	1 54	30	2.00
112	615,000	2 19	25	2.40
113	610,000	2 52	33	1.82
114	605,000	3 28	36	1.67
115	625,000	4 03	35	1.71
116	630,000	4 42	39	1.54
117	630,000	5 26	44	1.36
118	610,000	6 07	41	1.46
Stop...	....	....	....	....
119	550,000	0 00	....	....
120	580,000	0 43	43	1.395
121	570,000	1 17	34	1.76
122	580,000	1 59	42	1.43
123	....	....	....	....
124	540,000	3 17	78	.77
125	580,000	3 57	40	1.50
126	580,000	4 35	38	1.58
127	609,000	5 14	39	1.54
128	600,000	6 07	61	1.175
129	580,000	6 31	24	2.50
130	550,000	7 05	34	1.76
131	580,000	7 35	30	2.00
132	600,000	8 04	29	2.07
133	600,000	0 00	....	....
134	450,000	0 47	47	1.28
135	530,000	2 18	91	.66
136	520,000	3 05	47	1.28
137	540,000	3 39	34	1.76
138	545,000	4 32	53	1.13
139	540,000	5 22	50	1.20
140	545,000	6 11	49	1.22
141	555,000	7 05	54	1.11
142	560,000	8 09	....	....
Stop...	....	....	....	....
143	530,000	0 00	....	....
144	540,000	0 42	42	1.43
145	545,000	1 20	38	1.58
146	545,000	1 55	35	1.71
147	540,000	2 26	31	1.935
148	560,000	3 08	42	1.43
149	550,000	4 08	60	1.00
150	550,000	4 55	47	1.28
151	560,000	5 26	31	1.935
152	570,000	6 38	72	.833
153	565,000	7 46	68	.882
154	540,000	8 50	64	.938
155	450,000	9 54	64	.938
156	320,000	10 59	65	.924
157	100,000	12 14	75	.80
158	0	....	....	....

PROJECTILE NO. 6.

1½-INCH SPLIT BAND, AS SHOWN ON DRAWING 75-12-1.

Shore hardness before test, 16.
Shore hardness after test, 17.

Chemical analysis of band.

	Per cent.
Cu	99.7
Ni	None.
Mn	None.
Fe	0.16

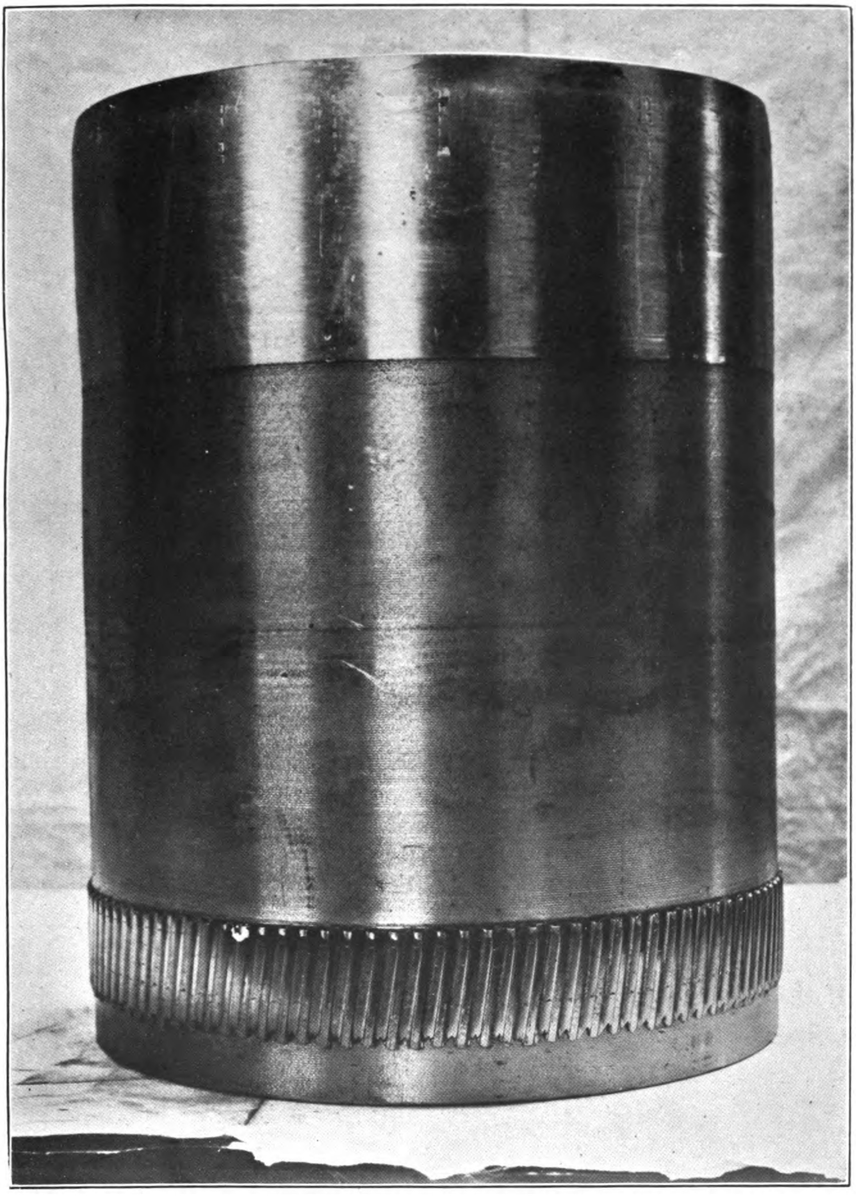
Appearance of projectile and band after test: Extrusion or "lacing" of band rather irregular; no new scratches on bourrelet of projectile.

Diameter at bottom of grooves in band equals diameter across lands in gun; diameter, 12.022 inches.

Remarks: Gun cleaned with wire and bristle brushes; bore slightly lubricated with Keystone grease; projectile traversed the bore fairly smoothly with very little bumping.

Projectile No. 6, 1½-inch split band.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
0.1	30,000	0	00		
.2	67,000		36	36	0.1667
.3	136,000	1	31	55	.109
.4	226,000	2	29	58	.1035
.5	297,000	3	31	61	.0985
.6	337,000	4	24	53	.113
.7	367,000	5	21	57	.105
.8	398,000	6	05	44	.136
.9	418,000	6	42	37	.162
1	430,000	7	11	29	.206
1.1	422,000	7	38	27	.222
1.2	414,000				
1.4	402,000	8	32	54	.334
1.6	405,000	9	14	42	.286
1.8	406,000	9	50	36	.334
2	380,000	10	11	21	.572
2.2	360,000	10	30	19	.632
2.5	342,000	10	47	17	1.06
3	374,000	11	31	44	.682
3.5	402,000	12	39	68	.44
4	436,000	14	02	83	.3615
4.5	459,000	15	13	71	.422
5	476,000	16	17	64	.469
5.5	478,000	17	14	57	.526
6	481,000	18	02	48	.625
6.5	480,000	18	34	32	.938
7	481,000	19	02	28	1.07
7.5	497,000	19	54	52	.576
8	509,000	20	53	59	.509
8.5	528,000	21	54	61	.491
9	551,000	22	57	63	.475
9.5					
10	593,000	24	20	83	.724
10.5	602,000	24	54	34	.883
11	599,000	25	36	42	.715
11.5	589,000	26	17	41	.732
12	592,000	27	01	44	.682
12.5	616,000	27	46	45	.666
13	639,000	28	33	47	.639
13.5	664,000	29	17	44	.682
14	669,000	29	52	35	.858
15	667,000	31	17	85	.706
16	689,000	32	54	97	.620
17	682,000	34	13	79	.760



PROJECTILE NO. 6, AFTER TEST; 1¼-INCH SPLIT BAND.

Projectile No. 6, 1½-inch split band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
18	677,000	35	04	51	1.176
19	657,000	35	43	39	1.54
20	630,000	36	40	57	1.05
21	610,000	37	27	47	1.275
22	593,000	38	14	47	1.275
23	573,000	38	43	29	2.07
24	573,000	39	10	27	2.22
Stop					
25	551,000	0	00		
26	544,000		44	44	1.36
27	533,000	1	28	44	1.36
28	532,000	2	18	50	1.20
29	539,000	3	35	77	.78
30	544,000	4	51	76	.79
31	543,000	5	55	64	.938
32	550,000	6	28	33	1.82
33	565,000	7	05	37	1.62
34	577,000	8	09	64	.938
Stop					
35	562,000	0	00		
36	569,000		44	44	1.344
37	563,000	1	18	34	1.76
38	573,000	1	59	41	1.46
39	583,000	3	11	72	.834
40	588,000	4	26	75	.80
41	602,000	0	00		
42	610,000	0	00		
43	597,000		39	39	1.54
44	602,000	1	38	59	1.017
45	618,000	3	04	86	.698
46	623,000	4	14	70	.857
47	624,000	5	01	47	1.278
48	627,000	5	41	40	1.50
49	628,000	6	34	53	1.13
50	623,000	7	53	79	.76
51	626,000	9	13	80	.75
52	632,000	10	06	53	1.13
53	633,000	10	46	40	1.50
54	616,000	11	35	49	1.22
55	612,000	12	47	72	.834
56	608,000	14	07	80	.75
57	603,000	15	01	54	1.11
58	599,000	15	37	36	1.667
Stop					
59	570,000	0	00		
60	636,000	3	22	202	.297
61	560,000	6	05	163	.368
62	550,000	8	57	172	.349
63	530,000	11	22	145	.414
64	555,000	13	25	123	.488
65	597,000	15	00	95	.632
66	608,000	16	38	98	.613
67	617,000	18	14	96	.625
68	582,000	19	20	66	.91
69	576,000	20	23	63	.952
70	600,000	21	36	73	.821
71	614,000	1	08	68	.883
72	620,000	2	00	52	1.15
73	560,000	2	52	52	1.15
74	538,000	4	14	82	.732
75	526,000	5	37	83	.723
76	520,000	6	40	63	.952
77	548,000	7	22	42	1.428
78	572,000	8	15	53	1.13
79	591,000	9	50	95	.631
80	603,000	11	32	102	.589
81	594,000	12	46	74	.81
82	597,000	13	36	50	1.20
Stop					
83	550,000	0	00		
84	547,000	1	16	76	.79
85	563,000	2	26	70	.858
86	560,000	3	24	58	1.035
87	573,000	4	33	69	.87
88	582,000	5	45	72	.834
89	592,000	6	52	67	.895
90	575,000	7	50	58	1.035

Projectile No. 6, 1¼-inch split band—Continued.

Distance along bore (inches).	Applied loads (pounds).	Elapsed time.		Time interval (seconds).	Velocity (inches per minute).
		M.	*s.*		
91	530,000	8	51	61	0.985
92	490,000	9	55	64	.938
93	537,000	10	52	57	1.05
94	570,000	11	47	55	1.09
95	530,000	12	53	66	.91
96	495,000	13	53	60	1.00
97	....	14	53	60	1.00
Stop					
98	504,000	1	15	75	.80
99	516,000	1	55	40	1.50
100	548,000	2	35	40	1.50
101	544,000	3	16	41	1.46
102	554,000	4	35	79	.76
103	564,000	6	24	109	.55
104	583,000	8	14	110	.545
105	574,000	9	26	72	.834
106	586,000	10	35	69	.870
Stop					
107	520,000	0	00	....	....
108	550,000	1	27	87	.69
109	559,000	2	06	39	1.54
110	555,000	2	45	39	1.54
111	553,000	3	21	36	1.67
112	558,000	4	17	56	1.07
113	556,000	5	16	59	1.018
114	543,000	6	09	53	1.13
115	548,000	6	46	37	1.62
116	564,000	7	24	36	1.67
117	571,000	8	12	48	1.25
118	561,000	9	10	58	1.035
Stop					
119	510,000	0	00	....	....
120	534,000		57	57	1.05
121	530,000	1	36	39	1.54
122	528,000	2	04	28	2.14
123	551,000	3	23	79	.76
124	542,000	4	40	77	.78
125	539,000	5	55	75	.80
126	530,000	6	54	59	1.017
127	540,000	7	45	51	1.175
128	559,000	9	20	95	.632
129	554,000	11	11	111	.54
130	524,000	12	52	101	.594
131	521,000	14	10	78	.77
132	562,000	16	21	131	.458
133	510,000	17	36	75	.80
134	474,000	18	35	59	1.017
135	500,000	20	06	91	.64
136	513,000	22	32	146	.41
137	516,000	24	56	144	.416
138	515,000	26	56	120	.500
139	509,000	29	20	144	.416
140	518,000	31	46	146	.41
141	515,000	33	58	132	.455
142	517,000	36	13	135	.445
Stop					
143	450,000	0	00	....	....
144	487,000	1	14	74	.81
145	494,000	2	21	67	.895
146	500,000	3	53	92	.652
147	499,000	6	03	130	.461
148	504,000	7	53	110	.545
149	486,000	9	07	74	.81
150	483,000	9	52	45	1.33
151	486,000	11	42	110	.545
152	485,000	13	18	96	.625
153	481,000	14	40	82	.732
154	481,000	15	31	51	1.178
155	420,000	17	08	97	.62
156	340,000	18	37	89	.615
157	190,000	19	45	68	.883
158	0	....		....	....

STEEL COLUMNS.

No. 542.

Built Steel Columns

Column tested with pin ends, Pins had axes, vertical in the plane of the web plate.

1 web plate 6 × ⅜-in.
4 angles 2½ × 2½ × ⅜-in.

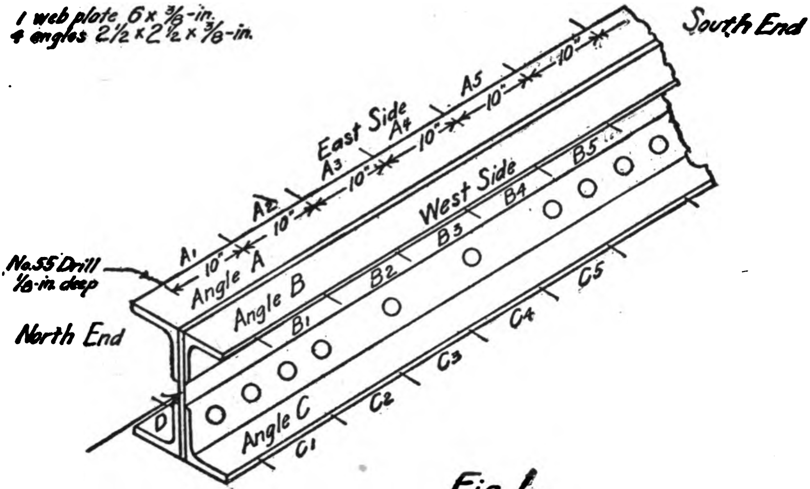


Fig. 1.

Built I column, 70,000 pounds carbon steel.
Length of column, 9 feet 5.80 inches.
See figure 2 for size of plate, angles, and location of rivets.

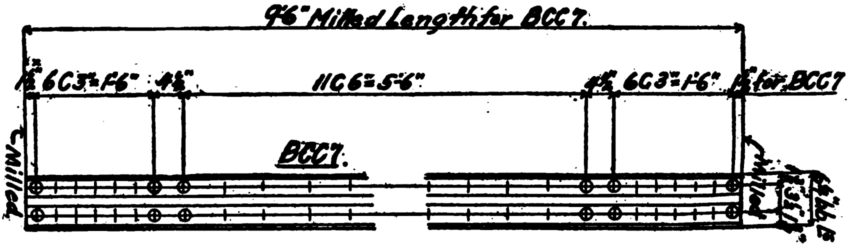
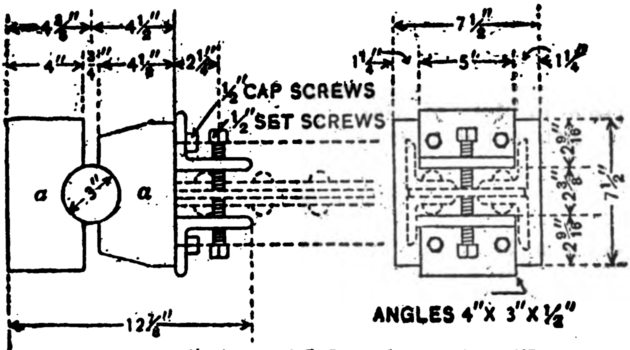


Fig. 2.

Total load.	Stress per square inch.		Co pre omn. read	9		10		Deflections.	
				Com-pressometer reading.	Com-pression.	Com-pressometer reading.	Com-pression.	Horizon-tal.	Vertical.
Pounds.	*Pounds.*		*In*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
9,396	1,024	A	0.	0.0124	0.	0.0141	0.	0.	0.
		B	.	.0021	0.	.0002	0.		
		C	.	.0144	0.	.0078	0.		
		D	.	.0068	0.	.0110	0.		
46,980	5,119	A	.20	.0146	.0022	.0169	.0028	0.	0.
		B	.18	.0038	.0017	.0017	.0015		
		C	.12	.0158	.0014	.0091	.0013		
		D	.09	.0074	.0006	.0112	.0002		
9,396	1,024	A	.01	—.0123	—.0001	.0143	.0002	0.	0.
		B	.	.0020	—.0001	.0004	.0002		
		C	.04	.0143	—.0001	.0080	.0002		
		D	.	.0069	.0001	.0110	0.		
93,960	10,239	A	.39	.0167	.0043	.0190	.0049	.01	0.
		B	.37	.0058	.0037	.0038	.0036		
		C	.24	.0168	.0024	.0109	.0031		
		D	.19	.0088	.0020	.0125	.0015		
140,940	15,360	A	.58	.0186	.0062	.0210	.0069	.01	0.
		B	.59	.0078	.0057	.0059	.0057		
		C	.41	.0188	.0044	.0129	.0051		
		D	.36	.0104	.0036	.0142	.0032		
187,920	20,479	A	.76	.0206	.0082	.0229	.0088	.02	0.
		B	.77	.0098	.0077	.0077	.0075		
		C	.58	.0196	.0052	.0145	.0067		
		D	.53	.0122	.0054.	.0162	.0052		
9,396	1,024	A	.04	.0126	.0002	.0145	.0004	0.	0.
		B	.02	.0024	.0003	.0004	.0004		
		C	.03	.0136	—.0008	.0080	.0002		
		D	.02	.0068	0.	.0110	0.		
234,900	25,600	A	.96	.0226	.0102	.0252	.0111	.02	0.
		B	.90	.0120	.0099	.0097	.0095		
		C	.60	.0215	.0071	.0163	.0085		
		D	.71	.0145	.0077	.0184	.0074		
9,396	1,024	A	.06	.0130	.0006	.0148	.0007	0.	0.
		B	.07	.0028	.0007	.0007	.0005		
		C	.08	.0140	—.0004	.0080	.0002		
		D	.03	.0069	.0001	.0111	.0001		
281,880	30,719	A	.16	.0250	.0126	.0277	.0136	.05	.01
		B	.25	.0145	.0124	.0118	.0116		
		C	.06	.0238	.0094	.0182	.0104		
		D	.02	.0170	.0102	.0212	.0102		
9,396	1,024	A	.10	.0134	.0010	.0158	.0017	0.	0.
		B	.13	.0034	.0013	.0015	.0013		
		C	.03	.0140	—.0004	.0084	.0006		
		D	.01	.0074	.0006	.0114	.0004		

Readings discont
Column graduallpounds, = 35,839 pounds per square inch.

Weight of column, 310 pounds.
Sectional area, 9.176 square inches.
Length, center to center of pins, 10 feet 2.50 inches.
Tested with pin ends. (See fig. 3.)



AXIS. OF PINS IN THE PLANE OF THE WEB.

Fig 3

Pins vertical in plane of web.
Gauged lengths as per figure 1.

No. 543.

Built I column, 70,000 pounds carbon steel.
Length of column, 9 feet 5.57 inches.
See figure 2 for size of plate, angles, and location of rivets.
Weight of column, 309 pounds.
Sectional area, 9.151 square inches.
Length, center to center of pins, 10 feet 2.45 inches.
Tested with pin ends. (See fig. 3.)
Pins vertical in plane of web.
Gauged length as per figure 1.

No. 544.

Built I column, 70,000 pounds carbon steel.
Length of column, 9 feet 5.80 inches.
See figure 2 for size of plate, angles, and location of rivets.
Weight of column, 309 pounds.
Sectional area, 9.145 square inches.
Length, center to center of pins, 10 feet 2.50 inches.
Tested with pin ends. (See fig. 3.)
Pins vertical in plane of web.
Gauged length as per figure 1.

Total load.	Stress per square inch.		Compressometer reading.	9		10		Deflections.	
				Compressometer reading.	Compression.	Compressometer reading.	Compression.	Horizontal.	Vertical.
Pounds.	*Pounds.*		*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
9,370	1,023	A	0.013	0.0076	0.	0.0184	0.	0.	0.
		B	.007	.0056	0.	.0068	0.		
		C	.014	.0072	0.	.0020	0.		
		D	.005	.0058	0.	.0096	0.		
46,850	5,119	A	.014	.0086	.0010	.0196	.0012	0.	0.
		B	.009	.0063	.0007	.0076	.0008		
		C	.015	.0095	.0023	.0044	.0024		
		D	.006	.0080	.0022	.0120	.0024		
9,370	1,023	A	.012	.0077	.0001	.0184	0.	0.	0.
		B	.007	.0060	.0004	.0070	.0002		
		C	.014	.0076	.0004	.0024	.0004		
		D	.005	.0060	.0002	.0098	.0002		
93,700	10,239	A	.017	.0100	.0024	.0210	.0026	.02	0.
		B	.011	.0082	.0026	.0086	.0018		
		C	.016	.0118	.0046	.0067	.0047		
		D	.008	.0103	.0045	.0144	.0048		
140,550	15,359	A	.019	.0116	.0040	.0228	.0044	.04	0.
		B	.013	.0096	.0040	.0102	.0034		
		C	.018	.0138	.0066	.0086	.0066		
		D	.010	.0122	.0064	.0168	.0072		
187,400	20,478	A	.021	.0134	.0058	.0247	.0063	.06	— 01
		B	.015	.0115	.0059	.0117	.0049		
		C	.019	.0157	.0084	.0103	.0083		
		D	.012	.0143	.0085	.0190	.0094		
234,250	25,615	A	.024	.0156	.0080	.0273	.0089	.09	—.01
		B	.016	.0136	.0080	.0134	.0066		
		C	.021	.0176	.0104	.0118	.0098		
		D	.014	.0162	.0104	.0217	.0121		
9,370	1,023	A	.013	.0079	.0003	.0186	.0002	0.	0.
		B	.008	.0062	.0006	.0065	—.0003		
		C	.014	.0082	.0010	.0030	.0010		
		D	.005	.0068	.0010	.0108	.0012		
281,100	30,738	A	.027	.0182	.0106	.0311	.0127	.19	—.01
		B	.018	.0163	.0107	.0151	.0083		
		C	.022	.0199	.0127	.0125	.0105		
		D	.018	.0182	.0124	.0262	.0166		
9,370	1,023	A	.014	.0083	.0007	.0192	.0008	.06	0.
		B	.009	.0068	.0012	.0077	.0009		
		C	.014	.0090	.0018	.0032	.0012		
		D	.006	.0070	.0012	.0128	.0032		

Readings discontin
Column gradually nds, = 32,787 pounds per square inch.

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Total load.	Stress per square inch.		9		10		Deflections.	
			Compressometer reading.	Compression.	Compressometer reading.	Compression.	Horizontal.	Vertical.
Pounds.	*Pounds.*		*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
9,145	1,000	A	0.0014	0.	0.0006	0.	0.	0.
		B	.0186	0.	.0188	0.		
		C	.0180	0.	.0002	0.		
		D	.0189	0.	.0033	0.		
45,725	5,000	A	.0026	.0012	.0016	.0010	0.	.01
		B	.0194	.0008	.0197	.0009		
		C	.0198	.0018	.0026	.0024		
		D	.0206	.0017	.0054	.0021		
9,145	1,000	A	.0014	0.	.0006	0.	0.	0.
		B	.0186	0.	.0190	.0002		
		C	.0182	.0002	.0004	.0002		
		D	.0188	−.0001	.0032	−.0001		
91,450	10,000	A	.0040	.0026	.0034	.0028	0.	.01
		B	.0210	.0024	.0210	.0022		
		C	.0218	.0038	.0041	.0039		
		D	.0222	.0033	.0078	.0045		
137,175	15,000	A	.0057	.0043	.0052	.0046	0.	.01
		B	.0224	.0038	.0226	.0038		
		C	.0237	.0057	.0060	.0058		
		D	.0251	.0062	.0098	.0065		
182,900	20,000	A	.0075	.0061	.0070	.0064	0.	0.
		B	.0241	.0055	.0241	.0053		
		C	.0256	.0076	.0079	.0077		
		D	.0266	.0077	.0120	.0087		
228,625	25,000	A	.0095	.0081	.0092	.0086	.01	0.
		B	.0258	.0072	.0259	.0071		
		C	.0276	.0096	.0100	.0098		
		D	.0284	.0095	.0137	.0104		
9,145	1,000	A	.0016	.0002	.0010	.0004	0.	.01
		B	.0188	.0002	.0191	.0003		
		C	.0188	.0008	.0016	.0014		
		D	.0190	.0001	.0038	.0005		
274,350	30,000	A	.0118	.0104	.0118	.0112	.03	0.
		B	.0280	.0094	.0278	.0090		
		C	.0300	.0120	.0120	.0118		
		D	.0296	.0107	.0159	.0126		
9,145	1,000	A	.0021	.0007	.0013	.0007	0.	0.
		B	.0190	.0004	.0194	.0006		
		C	.0195	.0015	.0018	.0016		
		D	.0194	.0005	.0041	.0008		
320,075	35,000	A	.0149	.0135	.0164	.0158	.09	0.
		B	.0304	.0118	.0298	.0110		
		C	.0328	.0148	.0138	.0136		
		D	.0316	.0127	.0190	.0157		

Readings discont

Column graduall = 36,807 pounds per square inch.

CHAIN.

TENSILE TESTS OF SPECIMENS OF CHAINS.

[Taken from fender chains for lock gates for Isthmian Canal Commission.]

Specimens consist of triplets or three links each.
Links made of wrought iron 3⅛ inches diameter.
Marks on specimen, 222–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15¼	15¾	15⅞
At 275,000 pounds the length was	16⅛	16¾	16⅝
Width of links before testing	12	11⅞	11⅞
At 275,000 pounds the width was	10½	10⅞	$10\frac{1}{16}$

At 450,000 pounds links were examined. At 479,000 pounds the third link fractured at weld.

Marks on specimen, 223–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	$15\frac{11}{16}$	15¾	15⅞
At 275,000 pounds the length was	$16\frac{11}{16}$	16¾	16⅝
Width of links before testing	12⅛	11⅞	12
At 275,000 pounds the width was	$10\frac{11}{16}$	$10\frac{11}{16}$	10¾

At 450,000 pounds the links were examined. At 510,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 221.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16	16	15⅞
At 275,000 pounds the length was	$17\frac{1}{16}$	17⅛	17⅝
Width of links before testing	12	12	12⅛
At 275,000 pounds the width was	10⅝	10¾	10⅝

At 450,000 pounds the links were examined; third link showed an opening at the welded end. At 490,000 pounds the second link fractured at the weld.

Marks on specimen, 222–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅞	15⅝	15¼
At 275,000 pounds the length was	17	16¾	16¼
Width of links before testing	12	12	11¼
At 275,000 pounds the width was	10¾	10¾	10⅝

At 396,000 pounds the second link fractured at weld.

Marks on specimen, 217–2.
Kind of links, stud.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16⅞	16¼	16½
At 300,000 pounds the length was	17⅜	16⅞	17
Width of links before testing	10⅞	10⅞	10⅞
At 300,000 pounds the width was	10⅜	10¼	10¼

At 500,000 pounds the links were examined. At 525,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 222–2–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅞	15 11/16	15⅞
At 245,000 pounds the length was	16⅝	16⅝	16¾
At 275,000 pounds the length was	17	16⅞	17
Width of links before testing	12⅛	11⅞	12
At 245,000 pounds the width was	10⅞	11	11
At 275,000 pounds the width was	10½	10½	10¾

At 450,000 pounds the links were examined. At 510,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 222–2–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15¾	15⅝	15
At 245,000 pounds the length was	16⅝	16⅜	16
At 275,000 pounds the length was	16¾	16¼	16
Width of links before testing was	12	11⅞	11⅞
At 245,000 pounds the width was	10⅛	11	10⅞
At 275,000 pounds the width was	10⅞	10¾	10¾

At 450,000 pounds the links were examined. At 510,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 222–3.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15¾	15½	15¾
At 245,000 pounds the length was	16⅝	16¼	16¼
At 275,000 pounds the length was	16¾	16¾	16¾
Width of links before testing	11	12	11⅞
At 245,000 pounds the width was	11	11	11
At 275,000 pounds the width was	10¾	10⅝	10¾

At 450,000 pounds the links were examined. Maximum load was 504,000 pounds. At 432,000 pounds the second link fractured at weld.

Marks on specimen, 223–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	15⅝	16
At 245,000 pounds the length was	16⅝	16¼	16⅞
At 275,000 pounds the length was	16⅞	16¾	17⅛
Width of links before testing	12	12⅛	12
At 245,000 pounds the width was	10⅞	11⅛	11
At 275,000 pounds the width was	10⅝	10⅞	10¾

At 450,000 pounds the links were examined. At 500,000 pounds the third link fractured at the weld.

Marks on specimen, 226–1.
Kind of links, stud.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16¼	16⅝	16 11/16
At 250,000 pounds the length was	16¾	16¾	16⅞
At 300,000 pounds the length was	17	16¾	17
Width of links before testing	10 11/16	10¾	10 11/16
At 250,000 pounds the width was	10¾	10¾	10¾
At 300,000 pounds the width was	10⅝	10¾	10⅝

At 500,000 pounds the links were examined. At 525,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 223–3.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	15⅞	15½
At 245,000 pounds the length was	16¼	16¼	16¼
At 275,000 pounds the length was	16¾	16⅞	16⅝
Width of links before testing	12	11⅞	12
At 245,000 pounds the width was	11	11	10⅞
At 275,000 pounds the width was	10¾	10⅞	10⅝

Maximum load was 370,000 pounds. At 346,000 pounds the first link fractured at the weld.

Marks on specimen, 224–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	15⅞	16
At 245,000 pounds length was	16½	16½	16¾
At 275,000 pounds length was	16⅞	16⅞	17
Width of links before testing	12	12	12
At 245,000 pounds width was	10⅞	11¼	11⅛
At 275,000 pounds width was	10¾	11	10⅞

At 450,000 pounds links were examined. Maximum load was 482,000 pounds. At 426,000 pounds the third link at the weld fractured.

Marks on specimen, 226–2.
Kind of links, stud.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16⅝	16⅝	16⅝
At 250,000 pounds the length was	16⅞	16⅞	16¾
At 300,000 pounds the length was	17	17	17
Width of links before testing	10⅞	10⅞	10⅞
At 250,000 pounds the width was	10¾	10¾	10¾
At 300,000 pounds the width was	10⅝	10⅝	10⅝

At 450,000 pounds the links were examined. At 525,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 224–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	15⅝	15¼
At 245,000 pounds the length was	16⅝	16⅝	16½
At 275,000 pounds the length was	17	17	16⅞
Width of links before testing	12⅛	12	12
At 245,000 pounds the width was	11	11	11
At 275,000 pounds the width was	10¾	10¾	10¾

At 450,000 pounds the links were examined. Maximum load was 464,000 pounds. At 422,000 pounds the third link at weld fractured.

Marks on specimen, 227–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	16	15¾
At 245,000 pounds the length was	16¼	16⅞	16⅞
At 275,000 pounds the length was	16¾	17⅛	17
Width of links before testing	12	12⅛	12
At 245,000 pounds the width was	11	11¼	10¾
At 275,000 pounds the width was	10¾	11	10½

At 450,000 pounds the links were examined. At 510,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 228–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16	16	15⅞
At 245,000 pounds the length was	17	16¾	16⅝
At 275,000 pounds the length was	17⅛	17	17
Width of links before testing	12	11¾	11¾
At 245,000 pounds the width was	11	11	10⅞
At 275,000 pounds the width was	10⅝	10¾	10⅝

At 450,000 pounds the links were examined. Maximum load was 469,000 pounds. At 410,000 pounds the first link at the weld fractured.

Marks on specimen, 223–3–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅞	15⅞	16
At 245,000 pounds the length was	16¾	16¾	16⅞
At 275,000 pounds the length was	17	17	17⅜
Width of links before testing	12 1/16	12 1/16	12
At 245,000 pounds the width was	11	11⅛	11
At 275,000 pounds the width was	10¾	10⅞	10¾

At 398,000 pounds the first link fractured at the weld.

Marks on specimen, 223–3–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅞	15⅞	15¾
At 245,000 pounds the length was	16¾	16¼	16⅝
At 275,000 pounds the length was	17¼	16¾	16⅞
Width of links before testing	12	12 1/16	11 15/16
At 245,000 pounds the width was	11	11⅛	11
At 275,000 pounds the width was	10¾	10⅞	10⅞

At 426,200 pounds the third link fractured at the weld.

Marks on specimen, 227–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16⅛	16 1/16	16
At 245,000 pounds the length was	17	17¼	17
At 275,000 pounds the length was	17½	17⅝	17½
Width of links before testing	12 1/16	12⅜	12 1/16
At 245,000 pounds the width was	11	11	11
At 275,000 pounds the width was	10¾	10½	10⅝

At 450,000 pounds the links were examined. At 480,000 pounds the first link fractured at the weld.

Marks on specimen, 224–3.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15¾	15⅝	15 9/16
At 245,000 pounds the length was	16¼	16⅝	16⅝
At 275,000 pounds the length was	17	16½	16¾
Width of links before testing	12	12 1/16	12
At 245,000 pounds the width was	11	11	11
At 275,000 pounds the width was	10⅝	10¼	10¾

Maximum load was 432,000 pounds. At 392,000 pounds the third link fractured at the weld.

Marks on specimens, 224–3–2.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15⅝	15¾	15⅝
At 245,000 pounds the length was	16¾	16⅞	16⅝
At 275,000 pounds the length was	16⅞	17⅛	16⅞
Width of links before testing	11⅞	12	12
At 245,000 pounds the width was	10⅞	11	11
At 275,000 pounds the width was	10⅝	10⅝	10¾

At 436,000 pounds the second link fractured at the weld and at quarter.

Marks on specimen, 224–3–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15 15/16	15⅞	15¼
At 245,000 pounds the length was	16⅞	16⅞	16¼
At 275,000 pounds the length was	17⅜	16⅞	16⅝
Width of links before testing	12	11⅞	11 15/16
At 245,000 pounds the width was	11	10⅞	10⅞
At 275,000 pounds the width was	10¾	10⅝	10⅝

At 450,000 pounds the links were examined. At 496,000 pounds the first link fractured at the weld and at center.

Marks on specimen, 227–3.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16	15⅞	15¾
At 245,000 pounds the length was	17	16¾	16¾
At 275,000 pounds the length was	17⅛	17	17
Width of links before testing	12	12	12
At 245,000 pounds the width was	11	11⅛	10⅞
At 275,000 pounds the width was	10¾	10⅝	10¾

At 450,000 pounds the links were examined. At 510,000 pounds the test was discontinued. Links not fractured.

Marks on specimen, 230–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	16	15⅞	15⅞
At 245,000 pounds the length was	16½	16¾	17
At 275,000 pounds the length was	16 11/16	17⅜	17⅛
Width of links before testing	12	12	12
At 245,000 pounds the width was	10¾	11	11
At 275,000 pounds the width was	10⅝	10¾	10¾

At 450,000 pounds the links were examined. At 491,000 pounds the first link fractured at the weld.

Marks on specimen, 229–1.
Kind of links, open.

	Links.		
	1	2	3
	Inches.	*Inches.*	*Inches.*
Length of links before testing	15¾	16	15¾
At 245,000 pounds the length was	16¼	16⅜	16⅜
Width of links before testing	12⅜	11⅞	11⅞
At 245,000 pounds the width was	10⅝	11⅝	10⅝

At 250,000 pounds the second link fractured at the weld.

PROOF STRESS APPLIED TO SLING CHAINS FOR WATERTOWN ARSENAL.

Nominal size of wire in chain, three-fourths inch.
Proof stress required, 16,000 pounds tension.
Elongations measured on length of 48 inches.
Sling chain consists of two lengths of chain with hooks at the ends. The other ends are connected to rings.

Two lengths, 1½-inch ring, 6 inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.76 inch.	0.76 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	1.95	1.90
200	1.76	1.75

Two lengths, 1¾-inch ring, 5¾ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.75 inch.	0.75 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	....	1.48
200	....	1.31

Part A. At 14,900 pounds the second link from hook fractured.

Two lengths, 1⁵⁄₁₆-inch ring, 4½ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.[

Diameter of wire..	0.74 inch.	0.74 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.96	2.88
200	2.86	2.70

Two lengths, 1¾-inch ring, 5½ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.75 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.09	1.89
200	1.95	1.80

Two lengths, 1½-inch ring, 6 inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.75 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.20	2.43
200	2.09	2.32

Links in both parts were stiff before test, and were also stiff after test.

Two lengths, 1½-inch ring, 6 inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.75 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.50	1.85
200	2.40	1.80

Part B. Links rather stiff before test. Scarf from twenty-third link from ring opened.

Two lengths, 1⅝-inch ring, 6½ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.74 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.61	....
200	2.60	0

Part B. First link fractured at 12,400 pounds (link next to hook).

Two lengths, 1½-inch ring, 5¾ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.73 inch.	0.74 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	2.45	2.55
200	2.34	2.45

Links rather stiff.

Two lengths, 1¼-inch ring, 6½ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.75 inch.	0.76 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
16,000	1.90	1.64
200	1.84	1.53

Nominal size of wire in chain, ½ inch.

Proof stress required, 7,000 pounds tension.

Elongation measured on length of 48 inches.

Sling chain consists of four and two lengths of chain with hooks at the ends. The other ends are connected to a 1½-inch ring, 5½-inches inside diameter.

Four lengths, ½ inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.52 inch.	0.52 inch.	0.52 inch.	0.52 inch.	Remarks.
Applied loads.	Part A.	Part B.	Part C.	Part D.	
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
200	0	0	0	0	Initial load..
7,000	2.25	1.49	2.04	1.96	
200	2.09	1.36	1.93	1.83	

[Elongation in 48 inches.]

Diameter of wire..	0.52 inch.	0.52 inch.	0.52 inch.	0.52 inch.	Remarks.
Applied loads.	Part A.	Part B.	Part C.	Part D.	
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
200	0	0	0	0	
7,000	2.64	2.55	2.56	2.64	
200	2.50	2.44	2.40	2.49	

Four lengths, ½-inch chain, 1½-inch ring, 5 inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire...	0.49 inch.	0.48 inch.	0.48 inch.	0.49 inch.	Remarks.
Applied loads.	Part A.	Part B.	Part C.	Part D.	
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
200	0	0	0	0 At 6,400 pounds fractured the fifteenth link from the hook.	
7,000	1.89	1.65	2.66	....	
200	1.75	1.55	2.54	....	All the links were stiff after test.

Two lengths, 1⅛-inch ring, 6¾ inches inside diameter, ½-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.48 inch.	0.48 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
7,000	....	....
200	....	....

Part A. At 6,300 pounds fractured the nineteenth link from the hook. Fractured at the weld.

Part B. At 5,500 pounds fractured the fifth link from the hook. Fractured at the weld.

Two lengths, 1-inch ring, 5½ inches inside diameter, ½-inch chain.

Elongation in 48 inches.

Diameter of wire..	0.49 inch.	0.49 inch.
Applied loads.	Part A.	Part B.
Pounds	*Inch.*	*Inch.*
200	0	0
7,000	....	....
200	....	....

Part A. Twelfth link from the hook fractured at 4,800 pounds.
Part B. Second link from the hook fractured at 4,800 pounds.

Four lengths, 1-inch ring, 5¾ inches inside diameter, ½-inch chain.

Elongation in 36 inches.

Diameter of wire..	0.50 inch.	0.50 inch.	0.49 inch.	0.50 inch.
Applied loads.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
200	0	0	0	0
7,000	2.70	2.65	2.76	....
200	2.55	2.51	2.65	....

Part D. Third link from ring fractured at 7,000 pounds.

Three lengths, 1$\frac{1}{16}$-inch ring, 6 inches inside diameter, ½-inch chain.

Elongation in 36 inches.

Diameter of wire..	0.49 inch.	0.49 inch.	0.48 inch.
Applied loads.	Part A.	Part B.	Part C.
Pounds.	*Inches.*	*Inches.*	*Inches.*
200	0	0	0
7,000	1.74	2.14	1.94
200	1.60	2.04	1.85

Part B. Fractured the eye in hook at 7,000 pounds.

Two lengths, 1⅛-inch ring, 4¾ inches inside diameter, 7/16-inch chain.

Elongation in 48 inches.

Diameter of wire..	0.42 inch.	0.43 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
5,000	1.85	1.75
200	1.73	1.60

Part B. Link near hook rather bad.

Four lengths, 1¼-inch ring, 5¾ inches inside diameter, 7/16-inch chain.

Elongation in 48 inches

Diameter of wire..	0.42 inch.	0.49 inch.	0.42 inch.	0.42 inch.
Applied loads.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
200	0	0	0	0
5,000	2.60	0.49	1.83	2.75
200	2.49	.40	1.70	2.75

Part B is ½-inch chain.

Two lengths, 1½-inch ring, 5½ inches inside diameter, ⅝-inch chain.

[Elongation in 48 inches.]

Diameter of wire.	0.62 inch.	0.62 inch.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
11,000	3.80	3.80
200	3.72	3.70

Links rather stiff.

Four lengths, 1½-inch ring, 6½ inches inside diameter, ⅝-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.67 inch.	0.67 inch.	0.67 inch.	0.67 inch.
Applied loads.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
200	0	0	0	0
11,000	1.24	1.14	1.18	1.65
200	1.20	1.07	1.09	1.60

Two lengths, 2-inch ring, 7½ inches inside diameter, 1⅛-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	1.10 inches.	1.10 inches.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
[1]40,000	4.65	4.68
200	4.52	4.56

[1] See Kent, p. 307.

Links rather stiff.

Two lengths, 2-inch ring, 7½ inches inside diameter, 1⅛-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	1.10 inches.	1.11 inches.
Applied loads.	Part A	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
40,000	4.80	4.60
200	4.65	4.49

Links rather stiff.

Two lengths, 2-inch ring, 7½ inches inside diameter, 1⅛-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	1.10 inches.	1.10 inches.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
40,000	2.05	2.55
200	1.90	2.43

Two lengths, 2-inch ring, 7 inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire..	1.12 inches.	1.12 inches.
Applied loads.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
40,000	2.34	2.66
200	2.22	2.50

PROOF STRESSES APPLIED TO NINE SLING CHAINS FOR WATERTOWN ARSENAL.

Sling chains consist of two and four lengths of chain with hooks at the ends. The other ends are connected to a ring.

Proof stress applied was two-thirds the load laid down in memorandum 3363.

Elongation measured on a length of 48 inches.

Four parts, 1¼-inch ring, 5.75 inches inside diameter, ½-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.50 inch.	0.50 inch.	0.50 inch.	0.50 inch.
Applied load.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
200	0	0	0	0
4,667	0.35	0.33	0.30	0.23
200	0.22	0.20	0.20	0.13

Four parts, 1¼-inch ring, 5.57 inches inside diameter, ½-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.50 inch.	0.50 inch.	0.51 inch.	0.51 inch.
Applied load.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
200	0	0	0	0
4,667	0.21	0.25	0.26	0.25
200	0.06	0.14	0.15	0.14

Two parts, 1¼-inch ring, 5.50 inches inside diameter, ⅝-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.61 inch.	0.61 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
200	0	0
7,333	1.47	1.50
200	1.38	1.39

Two parts, 1½-inch ring, 6¼ inches inside diameter, 11/16-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.69 inch.	0.69 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
9,000	0.27	0.23
200	0.10	0.08

Two parts, 1 5/16-inch ring, 4¾ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.73 inch.	0.73 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
10,667	0.50	0.48
200	0.35	0.40

Two parts, 1½-inch ring, 6¼ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.72 inch.	0.72 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
10,667	0.94	1.03
200	0.75	0.85

Two parts, 1¾-inch ring, 5¾ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.73 inch.	0.74 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
10,667	0.62	0.45
200	0.41	0.27

Two parts, 1¾-inch ring, 5½ inches inside diameter, ¾-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.74 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
200	0	0
10,667	0.30	0.25
200	0.10	0.12

One part, 1⅛-inch links at the ends, 2.5 by 11 inches long inside dimensions, 1-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	1.00 inch.
Applied load.	Part A.
Pounds.	*Inch.*
200	0
20,000	0.50
200	0.30

PROOF STRESSES APPLIED TO SIX SLING CHAINS FOR WATERTOWN ARSENAL.

Sling chains consisted of two and four lengths of chain with hooks at the ends. The other ends were connected to a ring.

Proof stress applied was two-thirds of the load required.

Elongation measured on a length of 48 inches.

Four parts, 1¼-inch ring, 5½ inches inside diameter, ½-inch chain.

[Elongation in 48 inches.]

Diameter of wire..	0.52 inch.	0.51 inch.	0.51 inch.	0.51 inch.
Applied load.	Part A.	Part B.	Part C.	Part D.
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
[1]200	0	0	0	0
4,667	0.19	0.21	0.21	0.24
200	0.09	0.10	0.05	0.10

[1] Initial load.

Two parts, ⅝-inch chain, 1¼-inch ring, 5½ inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire..	0.61 inch.	0.61 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inches.*	*Inches.*
[1]200	0	0
7,333	1.14	1.19
200	1.09	1.14

[1] Initial load.

Two parts, ¾-inch chain, 1½-inch ring, 6 inches inside diameter.

]Elongation in 48 inches.]

Diameter of wire..	0.76 inch.	0.74 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
[1]200	0	0
10,667	0.41	0.90
200	0.25	0.71

[1] Initial load.

Two parts, ¾-inch chain, 1⅜-inch ring, 6.75 inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.74 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
[1] 200	0	0
10,667	0.41	0.35
200	0.34	0.26

[1] Initial load.

Two parts, ¾-inch chain, 1½-inch ring, 6 inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire..	0.74 inch.	0.73 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
[1] 200	0	0
10,667	0.21	0.45
200	0.13	0.24

[1] Initial load.

Two parts, ¾-inch chain, 1½-inch ring, 6 inches inside diameter.

[Elongation in 48 inches.]

Diameter of wire..	0.75 inch.	0.75 inch.
Applied load.	Part A.	Part B.
Pounds.	*Inch.*	*Inch.*
[1] 200	0	0
10,667	0.36	0.30
200	0.24	0.24

[1] Initial load.

Chain.

Diameter of wire.	Number of links.	Outside length of links.	Outside width of links.	Tensile strength.	Manner of failure.
Inch.		*Inches.*	*Inches.*	*Pounds.*	
0.57	9	2.62 to 2.68	1.88 to 1.95	18,900	Fractured third link of chain at welded end.
0.57	11	2.65 to 2.70	1.88 to 1.93	15,100	Fractured fourth link of chain at welded end.

FRICTION TEST OF BRONZES.

TESTS OF BRONZES FOR RELATIVE WEAR AND COEFFICIENT OF FRICTION.

The machine used in the test is shown in figure 1. The specimen after being machined to the radius of the wheel is placed in the holder A. It is held against the wheel by weights on the end of the lower lever B, which gives the load on the specimen. The friction load is read on the upper lever C. Specimens of four different kinds of bronze were tested under various conditions.

The composition of the bronzes was as follows:

Bronze.	Cu.	Sn.	Zn.	Pb.	Al.	Fe.	Mn.
A	59.14	0.88	37.37		0.76	1.58	0.22
B	83.28	13.0	3.71				
C	81.73	11.0	5.1	2.1			
D	60.40	0.49	38.56			0.11	

Physical properties.

Marks.	Tensile strength.	Elongation.	Contraction.
	Pounds per square inch.	*Per cent.*	*Per cent.*
A	62,400	34.0	81.6
B	19,600	1.5	2.0
C	15,800	2.0	2.0
D	52,500	48.5	46.2

OIL LUBRICATION.

A pan below the friction wheel was filled with machine oil and this fed to the wheel by a felt pad in contact with it at its lowest point. No changes were made in this oiling device from the time it was started until all the oil tests had been completed.

Each of the specimens A, B, C, and D was run for 200 hours, after which a second specimen of metal, A, was run for 200 hours at a bearing pressure of 600 pounds per square inch on the friction wheel. Three specimens of bronze B were then run at bearing pressures of 700, 800, and 900 pounds per square inch, respectively. It was found impossible to obtain any data on the specimen run at 900 pounds per square inch, owing to impossibility of running the machine any length of time, due to the excessive heating of the bearings and the seizing of the specimen. Each specimen was run about 10 hours before any readings were taken, in order to secure an even bearing on the wheel.

Readings were taken of the friction load, and readings of the speed of the friction wheel were taken by means of a revolution

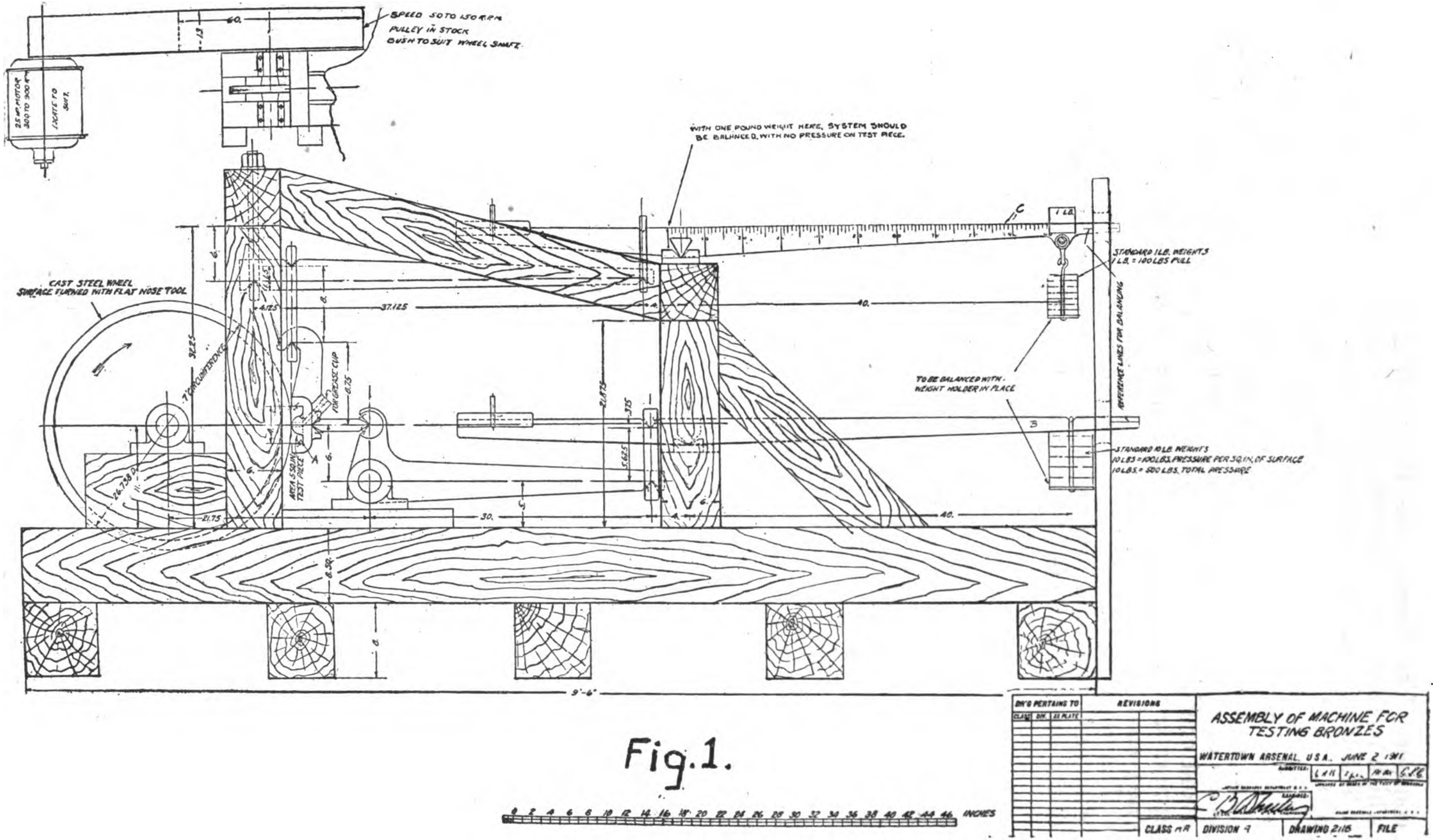
SPEED 50 TO 150 R.P.M.
PULLEY IN STOCK
BUSH TO SUIT WHEEL SHAFT.
60.
13
25 H.P. MOTOR
300 TO 900 R.P.M.
LOCATE TO SUIT.
WITH ONE POUND WEIGHT HERE, SYSTEM SHOULD BE BALANCED, WITH NO PRESSURE ON TEST PIECE.
C
1 LB.
STANDARD 1 LB. WEIGHTS
1 LB. = 100 LBS PULL
REFERENCE LINES FOR BALANCING
TO BE BALANCED WITH WEIGHT HOLDER IN PLACE
B
STANDARD 10 LB. WEIGHTS
10 LBS = 100 LBS. PRESSURE PER SQ. IN. OF SURFACE
10 LBS. = 500 LBS. TOTAL PRESSURE
CAST STEEL WHEEL
SURFACE TURNED WITH FLAT NOSE TOOL
7' CIRCUMFERENCE
26.738 D.
32.25
21.75
6.
4.125
37.125
8.
FOR GREASE CUP
8.75
AREA 5 SQ. IN. TEST PIECE
A
21.875
.375
5.625
30.
40.
8.50
9'-6"
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 INCHES
DR'G PERTAINS TO
CLASS
DIV.
AS PLATE
REVISIONS
ASSEMBLY OF MACHINE FOR TESTING BRONZES
WATERTOWN ARSENAL, U.S.A., JUNE 2 1911
SUBMITTED:
APPROVED:
CLASS
DIVISION
DRAWING 2115
FILE

Fig. 1.

counter. The former was the reading of the upper scale beam, which measured the tangential force exerted on the specimen.

The lever ratios were measured and found to be substantially correct. A check was obtained upon the accuracy of the upper system of levers which measured the friction load by suspending known weights in place of the specimen. The error was within 2 or 3 per cent, and decreased as the load was increased. The knife edges being of soft material (cast iron) were necessarily of large radius to avoid crushing. This accounts for the lack of sensitiveness in the apparatus. Usually the friction loads would be determined within one pound.

The wear of the specimen was obtained by weighing before and after each test, and also by measuring the thickness at the middle of the length by means of a micrometer. The test data is as follows:

Specimen A.

[Normal pressure, 600 pounds per square inch.]

Date.	Time.	Total hours run.	Speed (r.p.m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
Dec. 30	9	0	85	595	150	Weight of specimen, 16,865 grains.
Jan. 2	9	8	90	630	151	
	2	12.5	....	....	156	
	4	14.5	91	637	156	
3	10	17	90	630	157	
	12	19	90	630	157	
	2.45	21.25	91	637	155	
4	8	23	85	595	161	
	11	26	89	623	155	
	2.30	29	92	644	158	
	4	28.75	....	....	158	
5	9.30	31.5	86	602	155	Weight, 16,870 grains; thickness, 1.5563 to 1.5463 inches.
	1.30	35	....	....	148	
	3	36.5	90	630	145	
6	10.30	39.5	90	630	147	
	2	42.5	90	630	146	
8	10.45	48	90	630	145	
	11.45	48.75	89	623	145	
	3.30	52	90	630	144	
9	9	54	90	630	147	
	11.30	56.5	90	630	146	
	1.55	58.5	90	630	146	Shaft ran hot; run 8 hours with no load.
11	9	61.5	86	602	146	
	12.45	64.75	89	623	142	
	2.35	66.5	92	644	140	
	4	68	92	644	139	
12	8.20	68.75	86	602	147	
	11.45	72	91	637	141	
	1.50	73.25	91	637	143	
	4	75.75	91	637	143	Weight, 16,858 grains; thickness, 1.5561 to 1.5470 inches.
13	12.45	76	87	609	137	
	2.30	77.75	90	630	131	
	4.15	79.5	92	644	136	
15	9.30	81.25	90	630	137	
	1.30	84.75	91	637	137	
	3	86.25	91	637	137	
16	9	88.75	....	....	136	
	11.30	91.25	89	623	136	
	1	92.25	90	630	136	
17	8.15	96	83	581	140	
	11	98.75	89	623	140	
	1.30	100.75	90	630	140	Weight, 16,853 grains; thickness, 1.546 to 1.556 inches. Motor driving the apparatus required about 4 to 5 amperes at 220 volts.

Specimen A—Continued.

SECOND 100 HOURS.

Date.	Time.	Total hours run.	Speed (r.p.m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks
Feb. 26	9	101.75	84	588	138	Weight, 16,847 grains; thickness, 1.5457 to 1.5560 inches.
	2	105.75	91	637	132	
	4	107.75	92	644	130	
27	10.45	111.5	91	637	135	
	11.15	112	91	637	134	
	1.15	113	88	616	135	
	4.45	116.5	91	637	135	
28	8.15	117	87	609	134	
	12	120.75	....	....	132	
	2	121.75	91	637	132	
29	8.30	125.25	86	602	133	
	1	128.75	....	....	134	
	2.15	130	90	630	133	
Mar. 1	8.30	133.25	86	602	133	
	1	136.75	89	623	134	
2	8.15	141	85	595	133	
	11.30	144.25	89	623	131	
	1.30	145.25	89	623	131	
4	9	149.75	87	609	133	
	2.15	154	91	637	133	
5	9	157.75	88	616	129	
6	2	169.75	91	637	130	
	3.45	171.5	89	623	130	
7	10.15	175	90	630	130	
	4.45	180.5	92	644	130	
8	9	181.75	87	609	130	
	4	187.75	91	637	130	
9	8.30	189.25	89	623	133	
	11.15	192	90	630	130	
11	10.30	199.25	89	623	133	
	3.30	203.25	92	644	130	
12	8.15	205	86	602	131	Weight, 16,845 grains; thickness, 1.5559 to 1.5448 inches.

Specimen B.

[Normal pressure, 600 pounds per square inch.]

Date.		Time.	Total hours run.	Speed (r. p. m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
Jan.	19	8.15	0.5	88	616	127	Weight, 16,980 grains; thickness, 1.5448 to 1.5579 inches.
		11	3.25	90	630	118	
		12.45	4.5	88	616	120	
		4.15	8	....	....	120	
	20	9	9.25	87	609	121	
		11	11.25	89	623	122	
		1	12.75	91	637	121	
		3	14.75	90	630	119	
	22	8.15	16.5	87	609	120	
		11	19.25	89	623	120	
		1.30	21.25	90	630	120	
		3	22.75	92	644	119	
	23	10.15	26.5	91	637	119	
		1.30	29.25	92	644	119	
		3.15	31	91	637	119	
	24	1	36.75	91	637	118	
	25	9	41.25	88	616	120	
		1.15	45	90	630	119	
		4	47.75	91	637	117	
	26	11	51.25	89	623	120	
		2	53.75	90	630	120	
		4	55.75	....	....	120	
	27	8.30	56.75	88	616	122	
		11.15	59.5	89	623	120	
		2	61.75	90	630	122	
		4	63.75	92	644	121	
	29	8.15	64.5	84	588	121	
		1.15	69	90	630	120	
		4	71.75	91	637	120	
	30	8.30	72.75	85	595	119	
		12	76.25	90	630	119	
		2	77.75	91	637	120	
	31	8	80.25	86	602	120	
		1	84.75	91	637	120	
		3.15	87	93	651	118	
Feb.	1	9.30	89.75	89	623	119	
		11	91.25	90	630	119	
		2	93.75	91	637	120	
		4	95.75	92	644	120	
	2	9.30	97.75	89	623	119	
		1	100.75	89	623	118	Weight, 16,970 grains; thickness, 1.5438 to 1.5515 inches; current, 4 amperes.

SECOND 100 HOURS.

Date.		Time.	Total hours run.	Speed (r. p. m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
Mar.	12	10.30	103.25	91	637	125	Weight, 16,970 grains; thickness, 1.5438 to 1.5515 inches.
		2.30	106.25	90	630	128	
		4.30	108.25	89	623	125	
	13	9.30	110.25	90	630	129	
		1.30	113.25	89	623	127	
		4.45	116.5	94	658	126	
	14	11	119.75	90	630	132	
		2	121.75	89	623	130	
	15	10	126.75	90	630	130	
		3	130.75	91	637	129	
	16	10.30	135.25	90	630	128	
		4.15	140.25	92	644	128	
	18	9.30	142.25	90	630	130	
		1	144.75	90	630	129	
		4	147.75	90	630	127	
	19	9	149.75	88	616	125	
		11.30	152.25	90	630	118	
	20	11.15	160	89	623	122	
		1.30	161.25	89	623	118	
	21	3.15	171	90	630	123	
	22	9.45	174.5	88	616	126	
		2.45	178.5	90	630	120	
	23	9.30	182.25	86	602	123	
		4.30	188.25	90	630	124	
	25	9.15	190	85	595	120	
		11.45	192.5	89	623	123	
		2.45	193	91	637	121	
	26	10.30	199.25	89	623	123	
		2.15	202	91	637	121	Weight, 16,958 grains; thickness, 1.5419 to 1.5513 inches.

Specimen C.

[Normal pressure, 600 pounds per square inch.]

Date.	Time.	Total hours run.	Speed (r. p. m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
Feb. 9	8.45	7.25	85	595	131	Weight, 16,915 grains; thickness, 1.5618 to 1.5583 inches.
10	8.30	7.75	84	588	123	
	2.15	12.50	90	630	121	
12	9.00	16.25	89	623	122	
	1.30	19.75	89	623	121	
13	9.00	24.25	87	609	121	
	3.45	30.00	91	637	121	
14	9.00	32.25	87	609	120	
	1.30	35.75	89	623	120	
15	9.30	40.75	89	623	120	
	11.45	43.00	90	630	120	
16	12.00	51.25	....	....	120	
	1.15	51.50	90	630	115	
	4.45	55.00	93	651	116	
17	8.45	56.00	87	609	107	
	2.15	60.50	92	644	108	
	5.00	63.25	94	658	107	
19	8.15	63.50	85	595	113	
	1.15	67.50	89	623	112	
20	10.30	73.75	90	630	111	
	2.30	76.75	90	630	110	
21	9.30	80.75	89	623	110	
	2.30	84.75	89	623	110	
	4.30	86.75	91	637	110	
23	8.15	87.50	86	602	115	
	4.45	95.00	90	630	113	
24	10.15	97.50	91	637	112	
	4.30	102.75	91	637	112	Weight, 16,905 grains; thickness, 1.5612 to 1.5583 inches. Current, 4 amperes.
	....	103.25	....	....	....	

SECOND 100 HOURS.

Mar. 27	8.45	104.00	89	623	109	Weight, 16,905 grains; thickness, 1.5612 to 1.5583 inches.
	1.00	107.00	88	616	109	
	4.30	110.75	91	637	107	
28	9.15	112.50	87	609	111	
	1.45	116.00	91	637	110	
	3.45	118.00	91	637	110	
29	8.30	119.75	86	602	111	
	10.15	121.50	88	616	110	
	3.45	126.00	91	637	109	
30	8.15	127.50	87	609	111	
	1.00	131.25	89	623	111	
	2.30	132.75	91	637	111	
Apr. 1	8.30	135.75	86	602	110	
	10.00	137.25	89	623	115	
	11.45	139.00	90	630	115	
2	8.15	143.50	87	609	121	
	10.00	145.25	89	623	111	
	2.00	148.25	89	623	111	
3	10.30	153.75	89	623	115	
	2.45	157.00	91	637	116	
	4.45	159.00	91	637	116	
4	9.00	160.25	89	623	116	
	10.30	161.75	91	637	117	
	1.45	164.00	91	637	114	
	4.00	166.25	92	644	116	
5	10.00	169.25	90	630	117	
	2.15	172.50	91	637	117	
	4.45	175.00	91	637	118	
6	8.00	175.25	86	602	115	
	10.45	178.00	89	623	118	
	3.30	181.75	92	644	114	
8	8.30	183.75	84	588	115	
	11.30	186.75	91	637	117	
	3.45	190.00	91	637	114	
9	8.15	191.50	87	609	116	
	10.00	193.25	88	616	118	
	2.30	196.75	91	637	118	
10	10.00	201.25	89	623	120	
	....	203.25	....	....	....	Weight, 16,900 grains; thickness, 1.5583 to 1.5611 inches.

Specimen D.

[Normal pressure, 600 pounds per square inch.]

Date.	Time.	Total hours run.	Speed (r. p. m).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
1912. June 7	1.00	0	....	....	156	Weight, 17,145 grains; thickness, 1.5757 to 1.5827 inches.
	1.45	0.75	87	609	142	
	5.00	4.00	94	658	140	
8	9.45	5.75	90	630	147	
	11.00	7.00	90	630	145	
	2.45	9.75	92	644	144	
10	8.45	12.34	89	623	123	
	2.30	18.12	89	623	116	
11	8.15	20.15	....	....	128	
	8.45	20.75	87	609	122	
	11.45	23.34	89	623	120	
	4.00	28.00	91	637	119	
12	8.45	28.75	89	623	122	
	11.30	31.50	91	637	121	
	3.00	34.00	91	637	118	
	4.30	35.50	92	644	118	
13	10.30	38.50	91	637	120	
	4.30	43.50	92	644	121	
14	8.15	44.25	86	602	125	
	11.45	47.75	90	630	121	
	3.00	50.00	91	637	118	
	4.45	51.75	91	637	119	
15	8.30	52.50	83	581	125	
	11.45	55.75	90	630	124	
	5.00	60.00	92	644	120	
17	8.15	60.25	86	602	129	
	10.45	62.75	91	637	122	
	1.30	64.50	89	623	118	
	3.15	66.25	88	616	119	
	4.45	67.75	92	644	119	
18	8.15	68.25	86	602	128	
	11.45	71.75	90	630	122	
	4.00	75.00	89	623	119	
	5.00	76.00	92	644	120	
19	8.15	76.25	86	602	126	
	11.45	79.75	92	644	123	
	2.15	81.25	92	644	119	
	4.30	83.50	92	644	119	
20	9.45	85.75	90	630	122	
	1.30	88.50	90	630	117	
21	8.15	92.25	84	588	123	
	10.30	94.50	90	630	119	
	3.00	98.00	92	644	119	
24	8.00	100.00	....	....	....	Weight, 17,143 grains; thickness, 1.5751 to 1.5826 inches.
July 18	9.15	101.15	87	609	120	
	4.30	107.30	92	644	117	
19	10.30	110.30	90	630	116	
	4.15	116.15	90	630	116	
23	1.05	133.05	86	602	119	
24	9.00	138.00	88	616	118	
	1.30	141.30	88	616	118	
	4.00	144.00	92	644	119	
25	1.15	149.15	90	630	119	
	4.45	152.45	93	651	119	Weight, 17,136 grains; thickness, 1.5737 to 1.5813 inches.
26	3.45	159.45	95	665	119	
27	4.00	165.00	....	....	....	
29	11.00	168.00	88	616	121	
	3.00	171.00	90	630	120	
30	10.00	175.00	90	630	121	
	2.30	178.30	90	630	119	
31	9.30	182.30	88	616	122	
	4.00	188.00	90	630	119	
Aug. 1	4.00	196.00	88	616	124	
2	10.30	199.30	89	623	124	
	4.30	204.30	90	630	124	Weight, 17,140 grains; thickness, 1.5731 to 1.5810 inches.

Second specimen from A.

[Normal pressure, 600 pounds per square inch.]

Date.	Time.	Total hours run.	Speed (r.p.m.).	Speed (feet per minute).	Friction load (lbs.).	Remarks.
1912. Sept. 27	9.00	0	86	602	140	Weight, 16,945 grains; thickness, 1.5609 to 1.5608 inches.
	11.00	2	91	637	136	
	4.00	6	90	630	136	
28	9.00	8	88	616	140	
	11.30	10.50	90	630	138	
30	9.00	12.00	90	630	139	
	3.00	17.00	91	637	140	
	4.30	18.50	90	630	139	
Oct. 1	9.00	20.00	91	637	138	
	4.00	26.00	90	630	138	Weight, 16,944 grains; thickness, 1.5609 to 11.5607 inches.
2	9.00	27.00	84	588	149	
	4.00	33.00	90	630	143	
3	3.00	40.00	91	637	144	
4	10.00	44.00	90	630	145	
	4.00	49.00	91	637	146	Weight, 16,944 grains; thickness, 1.5608 to 1.5606 inches.
5	1.00	54.00	87	609	127	
7	1.00	62.00	87	609	125	
	4.00	65.00	88	616	126	
8	1.00	70.00	88	616	127	
9	9.00	75.00	90	690	125	Weight, 16,944 grains; thickness, 1.5608 to 1.5606 inches.
	4.00	81.00	92	644	136	
10	11.00	85.00	92	644	136	
	4.00	89.00	91	637	137	
11	8.00	90.00	91	637	141	
	4.00	97.00	90	630	140	
14	8.30	98.50	88	616	137	
	12.00	102.00	91	637	140	
17	4.30	102.50	86	602	145	Weight, 16,943 grains; thickness, 1.5608 to 1.5606 inches.
18	5.00	111.00	....	....	....	
19	11.00	114.00	91	637	144	
	3.00	117.00	92	644	144	
21	8.15	119.25	84	588	149	
	1.15	123.25	89	623	146	
	3.00	125.00	....	....	....	Weight, 16,948 grains; thickness, 1.5607 to 1.5605 inches.
22	11.00	128.00	90	630	154	
	3.00	131.00	92	644	152	
23	10.00	135.00	91	637	153	
	2.00	138.00	92	644	153	
24	10.00	143.00	91	637	154	
	3.00	147.00	92	644	154	
25	10.00	151.00	91	637	154	
	1.00	153.00	....	....	....	Weight, 16,947 grains; thickness, 1.5607 to 1.5604 inches.
26	9.00	158.00	90	630	148	
	3.00	163.00	91	637	148	
28	10.00	167.00	90	630	149	
	3.00	171.00	90	630	149	
29	11.00	176.00	91	637	148	
	2.00	178.00	90	630	149	
30	10.00	183.00	91	637	148	
	3.00	187.00	92	644	149	
31	11.00	192.00	92	644	148	
	2.00	194.00	91	637	149	
Nov. 1	....	205.00	....	....	....	Weight, 16,947 grains; thickness, 1.5606 to 1.5602 inches.

Specimen B.

[Normal pressure, 700 pounds per square inch.]

Date.	Time.	Total hours run.	Speed (revolutions per minute.)	Speed (feet per minute.)	Friction load (pounds.)	Remarks.
1912. Oct. 1	8.30	7.50	81	567	168	Weight, 17,000 grains; thickness, 1.5362 to 1.5301 inches.
2	11.00	10.50	88	616	168	
	4.00	14.50	89	623	168	
3	8.00	15.50	85	595	168	
	4.00	22.50	87	609	168	
4	8.00	23.50	81	567	168	
	....	31.50	....	....	....	
6	....	....	....	....	....	Weight, 16,967 grains; thickness, 1.5335 to 1.5283 inches.
	9.30	31.50	82	574	168	
	4.00	37.00	90	630	168	
7	....	45.00	....	....	....	
8	1.00	49.00	87	609	165	
9	8.00	53.00	82	574	165	
	2.00	58.00	88	616	165	
10	8.30	61.50	85	595	165	
11	8.00	69.00	83	581	165	
	4.30	76.50	86	602	165	
	5.00	77.00	....	....	....	
14	4.00	83.00	87	609	165	
	5.00	84.00	....	....	....	
15	....	....	....	....	....	Weight, 16,965 grains; thickness, 1.5321 to 1.5263 inches.
15	8.30	84.00	83	581	165	

[Normal pressure, 800 pounds per square inch.]

1913. Sept. 4	10.00	0.50	88	616	187	Weight, 16,992 grains; thickness, 1.5422 to 1.5547 inches.
	10.30	1.00	88	616	187	
	3.00	4.50	90	630	187	
5	8.00	6.50	82	574	192	
	2.00	11.50	89	623	187	
6	8.00	14.50	84	588	187	
8	8.00	18.50	84	588	187	
	10.00	20.50	90	630	187	
	4.45	26.25	90	630	187	
	5.00	26.50	....	....	....	
9	....	....	....	....	....	Weight, 16,979 grains; thickness, 1.5403 to 1.5514 inches.
	10.00	26.50	87	609	187	
10	8.00	32.50	80	560	187	
	3.00	38.50	88	616	187	
11	8.00	40.50	78	546	187	
	3.00	46.50	89	623	187	
12	9.00	49.50	82	574	187	
13	10.00	56.50	81	567	187	
15	10.30	61.00	90	630	187	
	4.00	65.50	88	616	187	
16	9.00	67.50	85	595	187	
17	....	74.50	....	....	....	Ran warm. Had to stop the machine. Cleaned disk and started at 1.30 p. m.
17	2.00	75.00	86	602	216	Ran hot. Stopped at 3.30 p. m.
18	8.00	76.50	82	574	216	Running warm.
	3.30	....	....	....	....	Ran hot. Belts ran off.
	3.30	83.00	....	....	....	
19	8.00	....	....	....	....	Weight, 16,937 grains; thickness, 1.5478 to 1.5376 inches.

As both the friction load and speed of the friction wheel vary somewhat, an effort was made to find a relation between them, but none could be found. The speed of the wheel is low in the morning when the voltage of the current supplied to the electric motor is lower than later in the day. The friction wheel and specimen are both cold at starting, and the temperature rises gradually until it is impossible to bear the hand on them. While it is probable that the friction load is a function of the temperature, it is believed to be independent of the speed of the friction wheel within the range of variation found in this work. At least part of the fluctuation of the friction load is caused by lack of sensitiveness of the knife edges. The high values of friction load obtained for specimen A at first is probably due to the roughness of the friction wheel.

Wear of specimens.

[600 pounds per square inch bearing pressure.]

Specimen.	Loss in weight (grains).		Decrease in thickness (inches).	
	During first 100 hours.	During second 100 hours.	During first 100 hours.	During second 100 hours.
A	12	2	0.0003	0.0005
B	10	12	.0007	.00105
C	10	5	.0003	.0001
D	2	7	.00035	.0014
A2	2	−4	.0002	.0003

Specimen B.

Bearing pressure.	Loss in weight.	Decrease in thickness.
Pounds.	*Grains.*	*Inch.*
700	35	0.0057
800	55	.0039

It was thought that the comparatively large loss of weight in specimen A might have been due to the rough-face friction-wheel surface, inasmuch as this specimen was the first one that was placed in the machine. Therefore, after the other four specimens had been run, a second specimen of A was tested. The results show certain unaccountable inconsistencies. During the period from 100 hours to 125 hours, the second specimen of A showed an increase in weight of 5 grains.[1] Before this the specimen showed consistent loss of weight, and in the weighings following the gain the specimen also showed consistent losses in weight, checking well with losses in a corresponding length of time during the first 100 hours. It seems, therefore, that the gain must have been due to a definite change in the scales, and should be treated as a constant error. Even if this is granted, the wear on the second specimen of A would be the least of any of the pieces, and the loss by weight of D would be second, although its total decrease in thickness equals that of B, which showed the greatest wear. C has the lowest coefficient of friction, with D and B following closely in that order.

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[1] This weighing was carefully made three times with the same results.

GREASE LUBRICATION.

For these tests the lubricating oil was removed and Keystone grease No. 2 supplied from a grease cup attached to the specimen shoe. The hole through the specimen holder was continued through the specimen, and oil grooves cut on the friction face nearly to the edges of the specimen. A weaker spring was substituted for the one in the grease cup. This allowed the cup to be screwed down by hand three or four times, which fed the grease for several minutes with fairly uniform friction load on the specimen.

The fact that the lubrication was satisfactory was indicated by the nearly uniform values of the friction load. When the grease cup was not screwed down at frequent intervals, the wheel evidently became dry, although apparently there was grease on the wheel and piled up on the top surface of the specimen in contact with the wheel. The upper edge of the specimen was well rounded in an unsatisfactory attempt to feed this grease to the bearing surfaces. Failure of the lubrication was indicated by violent fluctuations of the friction load, which often jumped to 400 or 500 pounds, with fluctuations of 200 to 300 pounds, also by great rise in temperature, the odor of overheated grease, and shrieking of the friction surfaces. If lubrication stopped for about half a minute, conditions became such that it was nearly impossible to continue the test.

The load was 600 pounds per square inch, and the oil cup was screwed down as tightly as convenient with the hand each minute, and a reading of the friction load taken within 15 or 20 seconds.

A preliminary run of 10 to 15 minutes was made on each specimen before taking these readings, in order to obtain conditions which were uniform for the new lubricant. The test data follows:

Friction load.

[Pounds.]

Time run (minutes).	Specimen A.		Specimen B, grease.	Specimen C, grease.
	Grease.	Grease.		
1	175	[1] 200	196	165
2	169	148	177	136
3	160	146	176	129
4	160	155	164	127
5	164	159	152	125
6	165	180	151	125
7	165	190	148	119
8	166	200	136	116
9	175	163	133	116
10	[2] 176	170	130	113
11	185		125	114
12	169		123	113
13	159		124	114
14	165		124	114
15	168		122	113
16	165		123	112
17	162		123	112
18			125	
19			127	
20				

[1] These readings were taken after testing specimens A, B, and C, in the order named.
[2] The grease cup was filled at that time.

The rapid decrease in the friction load after starting each test is probably caused by the increase in the temperature of the specimen. As the grease is fed through a hole in the latter, an increase in temperature increases its fluidity until it approaches the viscosity of the lubricating oil previously used. This is indicated by the values of the friction loads for the two lubricants. The values for specimens B and C are identical within the errors of observation. The second test of specimen A, shown by dotted lines on the diagram, was made after testing the three specimens, as the lower values for friction load obtained for specimens B and C indicated that the high temperature reached after operating for some time decreased the friction. The fact that practically the same values were obtained for both tests on specimen A shows that this material has a higher coefficient of friction for grease than for oil, and that it fluctuates much more than for specimens B and C. These tests could not be continued long enough to obtain data on the wear of the specimens.

Coefficient of friction and wear.

[For velocity of 600 feet per minute.]

Specimen.	Bearing pressure (pounds per square inch).	Average friction load (pounds).	Coefficient of friction.	
			"Oil."	"Grease."
A	600	132	0.044	0.0543
B	600	123	.041	.0406
C	600	118	.0393	.039
D	600	....	.0403	....
A2	600	....	.048	....
B	700	166.5	.0476	....
B	800	190	.0475	....

Specimen.	Bearing pressure (pounds per square inch).	Wear for 1 square inch bearing surface (in pounds per 1,000,000 feet).	
		"Oil."	"Grease."
A	600	0.0000154	0.0001345
B	600	.0000844	.000235
C	600	.0000575	.0000537
D	600	.0000348	....
A2	600	.0000116	....
B	700	.000331	....
B	800	.000526	....

The loss in weight of specimen A for the first 100 hours is omitted and the readings for the second 100 hours averaged in computing the wear. The loss of weight of the second specimen of A is assumed to be 3 grains in the computation of the wear.

This experiment is being continued on other bearing bronzes.

WIRE ROPE.

WIRE ROPE.

WIRE ROPE.

[Rope prepared for testing with closed sockets at the ends. All specimens had hemp cores.]

Description.	Nominal size, diameter.	Length between sockets.	Actual size, diameter.	Number of strands.	Number of wires per strand.
	Inches.	*Ft. In.*	*Inches.*		
Galvanized flexible wire rope	¼	17 6	0.29	6	18
Plow-steel crane rope[1]	⅜	7 0	.38	6	37
Cast-steel wire rope	⅜	5 9	.38	6	19
Hoisting rope[1]	⅜	6 0	.38	6	37
Plow steel	9/16	9 8	.53	8	19
Plow-steel hoisting rope	9/16	9 5½	.57	8	19
Steel-wire rope	9/16	5 6½	.58	6	19
Plow-steel hoisting rope	9/16	5 4	.58	8	19
Plow-steel crane rope	⅞	9 6	.94	6	37
Plow-steel hoisting rope	1	9 4½	1.03	6	37
Do	1	9 5	1.03	6	37
Do	1	9 3½	1.03	6	37
Steel-wire hoisting rope	1	10 ½	1.05	6	19
Cast-steel hoisting rope	1½	9 0	1.52	8	19
Steel-wire hoisting rope	1½	9 7½	1.61	6	25

Description.	Diameter of wire.	Breaking strength.	Parted.
	Inch.	*Lbs.*	
Galvanized flexible wire rope	0.018	5,900	1 strand, 66 inches from end of socket.
Plow-steel crane rope[1]	.017	11,100	5 strands at the jaws.
Cast-steel wire rope	.027	10,100	3 strands, 12 inches from end of socket.
Hoisting rope[1]	.017	10,600	5 strands at the jaws.
Plow steel	.028	28,800	4 strands at end of socket.
Plow-steel hoisting rope	.033	25,500	4 strands, 6 inches from end of socket.
Steel-wire rope	.032-.041	21,200	3 strands, 14 inches from end of socket.
Plow-steel hoisting rope	.025-.033	20,900	6 strands at the end of socket.
Plow-steel crane rope	.045	62,900	3 strands at middle of length.
Plow-steel hoisting rope	.037-.052	85,900	Do.
Do	.039-.055	73,500	3 strands, 16 inches from end of socket.
Do	.045	81,700	2 strands, 8 inches from end of socket.
Do	.067	77,700	4 strands, 52 inches from end of socket.
Cast-steel hoisting rope	.066-.090	120,100	3 strands, 22 inches from end of socket.
Steel-wire hoisting rope	.041-.10	83,700	3 strands, 35 inches from end of socket.

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[1] Rope tested with lead jaws.

MANILA ROPE.

MANILA ROPE (3 STRAND).

[Rope prepared for testing with eye splices at the ends, and then wetting the rope.

Nominal size.		Length of sample.		Length between splices.	Weight of sample.		Breaking length.	Circumference.	Diameter.	Sectional area.
Diameter.	Circumference.									
Inch.	*Inches.*	*Ft.*	*in.*	*Feet.*	*Lbs.*	*oz.*	*Feet.*	*Inches.*	*Inches.*	*Sq. inches.*
3/8	....	18	0	6	0	12	24,000	1.30	0.39	0.119
7/16	....	18	0	6	1	4	21,600	1.65	.50	.196
1/2	....	17	10	6	1	14	20,924	1.70	.54	.23
	2.00	18	0	6	2	6	33,340	2.25	.76	.45
	2.25	17	11	6	2	7	22,598	2.40	.75	.442
	2.50	18	0	6	3	3	29,360	2.65	.87	.59
	4.00	17	9½	6	8	0	26,846	4.20	1.36	1.45
	4.00	17	10½	6	8	0	26,866	4.20	1.35	1.43
	4.00	18	0	6	8	0	28,125	4.20	1.36	1.45
	4.00	18	0	6	8	8	22,650	4.18	1.36	1.45
	4.00	18	0	6	8	8	22,650	4.15	1.36	1.45
	4.00	18	4	6	8	12	25,140	4.15	1.37	1.47
	4.00	17	10	6	9	8	18,770	4.45	1.42	1.58
	4.00	18	0	6	10	0	16,560	4.45	1.43	1.60
	4.00	18	2	6	9	0	18,570	4.36	1.45	1.65
	4.00	18	0	6	10	0	17,820	4.42	1.46	1.67
	4.00	18	1	6	10	0	17,890	4.42	1.43	1.60
	4.00	18	0	6	13	0	26,860	5.31	1.73	2.35

Nominal size.		Tensile strength.		Parted.
Diameter.	Circumference.	Load.	Stress (pounds per square inch).	
Inch.	*Inches.*	*Pounds.*		
3/8	....	1,000	8,403	1 strand, 11 inches from end of splice.
7/16	....	2,000	10,204	1 strand, 7 inches from end of splice.
1/2	....	2,200	9,565	1 strand, 30 inches from end of splice.
	2.00	4,400	9,777	1 strand, 11 inches from end of splice.
	2.25	5,400	12,217	1 strand, at the splice.
	2.50	5,200	8,813	1 strand, at middle of length.
	4.00	12,100	8,344	Do.
	4.00	12,800	8,951	1 strand, 15 inches from end of splice.
	4.00	12,500	8,620	Do.
	4.00	10,700	7,379	1 strand, at middle of length.
	4.00	10,700	7,379	1 strand, 12 inches from end of splice.
	4.00	12,000	8,163	1 strand, 11 inches from end of splice.
	4.00	10,000	6,329	1 strand, at end of splice.
	4.00	9,200	5,750	Do.
	4.00	9,200	5,570	Do.
	4.00	9,900	5,920	Do.
	4.00	9,100	5,680	Do.
	4.00	19,400	8,260	1 strand, at the splice.

CORDAGE.

CORDAGE.

Tensile tests of soft-laid shot lines for the United States Life-Saving Service, Washington, D. C.

[Shot lines to be soft laid and to be made of best sail twine.]

Diameter	inch	0.30
Lay, 1 turn in	do	1.50
Strands	number	3
Threads per strand	do	15
Length of sample tested	feet	15
Length between pins	do	6

No. of coil.	Weight of coil.	End of coil.	Tensile strength.	Parted.
	Pounds.		*Pounds.*	
1	35	Inside	1,135	1 strand at the pin.
2	35	...do	1,200	Do.
3	36	...do	1,160	1 strand at the middle.
4	35¼	...do	1,150	1 strand at the pin.
5	35¾	...do	1,245	1 strand 14 inches from the pin.
6	35¼	...do	1,200	1 strand at the pin.
7	35¼	...do	1,210	Do.
8	35¼	...do	1,230	Do.
9	35¾	...do	1,196	Do.
10	35¾	...do	1,220	Do.
11	35¾	...do	1,220	Do.
12	35½	...do	1,182	Do.
13	35¾	...do	1,205	Do.
14	36	...do	1,260	2 strands 5 inches from the pin.
15	35½	...do	1,098	1 strand 18 inches from the pin.
16	35½	...do	1,208	1 strand at the pin.
17	35½	...do	1,095	Do.
18	35¾	...do	1,252	1 strand at the middle.
19	35¾	...do	1,156	1 strand at the pin.
20	35½	...do	1,180	Do.
21	35¾	...do	1,163	Do.
22	36	...do	1,165	1 strand 14 inches from the pin.
23	36	...do	1,050	1 strand at the middle.
24	35½	...do	1,205	Do.
25	35½	...do	1,050	1 strand 11 inches from the pin.
26	35½	...do	1,136	1 strand 23 inches from the pin.
27	35¾	...do	1,158	1 strand at the pin.
28	36	...do	980	Do.
29	36	...do	1,080	1 strand 17 inches from the pin.
30	36	...do	1,205	1 strand at the pin.

RETEST OF THE FOLLOWING COILS.

No. of coil.	End of coil.	Tensile strength.	Parted.
		Pounds.	
1	Inside	1,220	1 strand 26 inches from the pin.
4	.....do	1,305	1 strand at the pin.
15	.....do	1,020	1 strand 18 inches from the pin.
[1] 15	.....do	1,252	1 strand at the pin.
17	.....do	1,180	1 strand 19 inches from the pin.
23	.....do	1,050	1 strand 16 inches from the pin.
[1] 23	.....do	1,092	1 strand 20 inches from the pin.
25	.....do	1,056	1 strand at the pin.
[1] 25	.....do	1,225	Do.
26	.....do	1,160	Do.
28	.....do	1,058	1 strand 18 inches from the pin.
[1] 28	.....do	1,095	1 strand at the pin.
29	.....do	1,110	Do.
[1] 29	.....do	1,146	Do.

[1] Third test.

RUBBER.

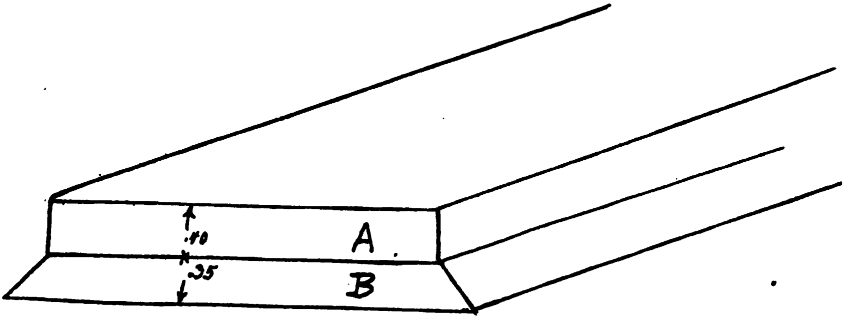
RUBBER.

Description.	Thickness.	Width.	Sectional area.	Tensile strength.		Elongation in 2 inches.	
				Load.	Stress (pounds per square inch).	Inches.	Per cent.
	Inch.	*Inches.*	*Sq. in.*	*Pounds.*			
Covering rubber	0.38	0.93	0.353	179	507	2.71	135.5
Do	.41	.97	.40	362	905	6.15	307.5
Do	.42	1.00	.42	285	678	5.90	295.0
Do	.43	.95	.408	367	899	6.00	300.0
Do	.44	1.02	.44	365	829	3.14	157.0
Do	.47	.98	.46	252	548	3.00	150.0
Do	.48	.98	.47	245	521	3.16	158.0
Do	.48	1.00	.48	291	606	4.90	245.0
Do	.49	1.02	.50	289	578	4.90	220.0
Do	.40	1.00	.49	385	785	5.11	255.5
Do	.49	1.00	.49	311	624	4.50	225.0
Red foundation	.53	.97	.51	225	441	5.05	252.5
Covering rubber	.57	1.00	.57	488	856	2.67	133.5
Do	.68	1.00	.68	485	713	4.45	225.5

TENSILE TEST OF A SAMPLE OF RUBBER TAKEN FROM A DETACHABLE TIRE FOR WATERTOWN ARSENAL.

Length over all, 8.50 inches.

Width, 2 inches. This was reduced to 1.25 inches for a length of 2.25 inches at the middle.



Elongations taken on gauge length of 2 inches on part A.

	Width.	Thickness.	Sectional area.	Tensile strength.		Elongation in 2 inches.	
				Load.	Stress (pounds per square inch).	Inch.	Per cent.
	Inches.	*Inch.*	*Sq. in.*	*Pounds.*			
Required					Not less than 600.		Not under 75. Not over 150.
Results	1.25	0.75	0.94	485	515	0.25	12.5

Fractured part B at edge of gauge length—test continued on part A.

Width.	Thickness.	Sectional area.	Tensile strength.		Elongation in 2 inches.		Parted.
			Load.	Stress (pounds per square inch).	Inches.	Per cent.	
Inches.	*Inch.*	*Sq. in.*	*Pounds.*				
1.25	0.40	0.50	234	468	2.10	105	Inside of gauge marks.

HOSE.

PNEUMATIC HOSE.

TUBE TEST.

Gauged length of 2 inches laid off on each sample; stretched to 6 inches for 10 minutes, and load removed.

Description.	Width.	Length.	Permanent set.
	Inches.	*Inches.*	*Inches.*
7-ply ¾ inch	1.00	6.00	0.24
7-ply ½ inch	1.00	6.00	.60
7-ply ¼ inch	1.00	6.00	.55
7-ply ¾ inch	1.00	6.00	.25

Friction test.

Description.	Unwound in 10 minutes.
	Inches.
7-ply ¾ inch	5.70
Do	5.60
7-ply ½ inch	4.90
Do	5.00
7-ply ¼ inch	5.25
Do	5.60
Do	4.90
Do	4.85

PROOF STRESSES ON PISTON RODS.

PROOF STRESSES.

PROOF STRESS APPLIED TO 1 PISTON ROD FOR 6-INCH DISAPPEARING CARRIAGE, MODEL OF 1905, M11.

[Proof stress required, 120,000 pounds tension.]

Elongation measured on gauge length of 30 inches, the first point of gauge length being 6 inches from piston head.

No. on rod.	Applied loads.		
	500 pounds.	120,000 pounds.	500 pounds.
On one end, 2 2961; on other end, 11 352	0	0.0175	0

Proof stress of 120,000 pounds tension was applied to rod without signs of failure.

PROOF STRESS APPLIED TO 3 PISTON RODS FOR 14-INCH DISAPPEARING CARRIAGE, MODEL OF 1907 M1.

[Proof stress required, 575,000 pounds tension.]

Elongation measured on gauge length of 30 inches, the first point in gauge length being about 30 inches from piston head

No. on rod.	Applied loads.		
	5,000 pounds.	575,000 pounds.	5,000 pounds.
1427-3	0	0.0212	0
1426-4	0	.0217	0
1432-5	0	.0214	0

Proof stress of 575,000 pounds tension was applied to each rod without signs of failure.

PROOF STRESS APPLIED TO 12 PISTON RODS FOR 6-INCH DISAPPEARING CARRIAGE, MODEL OF 1905 M11.

[Proof stress required, 120,000 pounds tension.]

Elongations measured on gauge length of 30 inches, the first point of gauge length being 6 inches from piston head.

No. on rods.	Applied loads.		
	500 pounds.	120,000 pounds.	500 pounds.
1	0	0.0184	0.
2	0	.0181	0.
3	0	.0184	0.0001
4	0	.0183	.0001
5	0	.0183	0.
6	0	.0184	.0001
7	0	.0181	0.
8	0	.0182	0.
9	0	.0184	.0001
10	0	.0183	.0001
11	0	.0183	0.
12	0	.0183	.0001

Proof stress of 120,000 pounds tension was applied to each rod without signs of failure.

PROOF STRESS APPLIED TO 2 PISTON RODS FOR 14-INCH DISAPPEARING CARRIAGE, MODEL OF 1907 M1.

[Proof stress required, 575,000 pounds tension.]

Elongation measured on gauge length of 30 inches, the first point in gauge length being about 30 inches from piston head.

No. on rod.	Applied loads.		
	5,000 pounds.	575,000 pounds.	5,000 pounds.
1424	0	0.0212	0.
1428	0	.0213	.0001

Proof stress of 575,000 pounds tension was applied to each rod without signs of failure.

PROOF STRESS APPLIED TO 2 PISTON RODS FOR 15-POUNDER BARBETTE.

[Proof stress required, 98,400 pounds tension.]

Elongation measured on gauge length of 10 inches, the first point in gauge length being about 9.50 inches from end of rod.

No. on bronze piston head.	Applied loads.		
	500 pounds.	98,400 pounds.	500 pounds.
7383	0	0.0077	0
7416	0	.0079	0

Proof stress of 98,400 pounds tension was applied to each rod without signs of failure.

TEST OF PISTON ROD NO. 31, FOR 12-INCH MORTAR CARRIAGE, MODEL OF 1896 M111.

The rod was tested under a load of 565,500 pounds compression in cylinder, with results as follows:

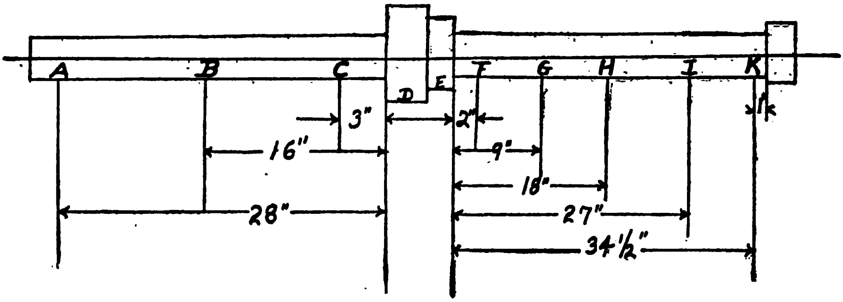
[Compression in 20 inches.]

No. on rod.	Applied loads.		
	5,000 pounds.	565,500 pounds.	5,000 pounds.
31	0	0.0454	0.0059

The rod was then swung on centers in a lathe, and the deformations measured at various points as indicated in the sketch below:

Amount of bend.

	Inch.		*Inch.*
A	0.007	F	0.063
B	.024	G	.070
C	.043	H	.070
D	.049	I	.043
E	.045	K	.010

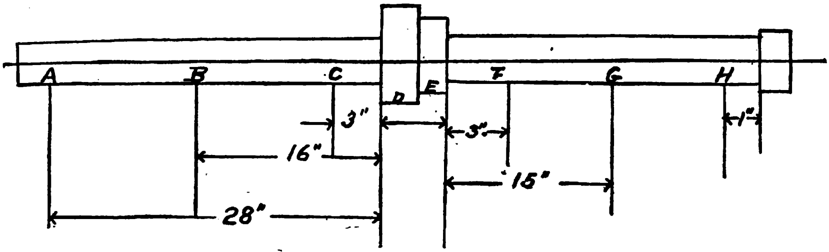


TEST OF PISTON ROD NO. 37, FOR 12-INCH MORTAR CARRIAGE, MODEL OF 1896 M111.

The rod was first swung in a lathe and showed the following deformations:

Amount of bend.

	Inch.		*Inch.*
A	0.001	E	0.001
B	.001	F	.002
C	.001	G	.002
D	.001	H	.001



The apparatus was then checked up and the results are shown on sketch above. No cause for eccentric loading was found. The stress on the cast-iron pipe supports under a load of 565,500 pounds is 17,570 pounds per square inch.

The results of the proof stress are as follows:

[Compression in 20 inches.]

Number on rod.	Applied loads.		
	5,000 pounds.	565,500 pounds.	5,000 pounds.
37	0	0.0579	0.0200

The rod was again swung in a lathe and showed the following deformations (see sketch):

Amount of bend.

	Inch.		*Inch.*
A	0.009	E	0.066
B	.028	F	.073
C	.051	G	.076
D	.056	H	.016

The maximum deformation at G was in a plane nearly perpendicular to the axis of the pin and trunnion of the support used. The deformation, however, did not remain maximum in this plane but changed rapidly as if the rod had been twisted.

SPRINGS.

SPRINGS.

COMPRESSIVE TESTS OF 42 SPRINGS FOR 12-INCH MORTAR CARRIAGE.

Free height: Maximum, 7.54 inches; minimum, 7.17 inches.

Height after being closed down solid for 48 hours—Free height: Maximum, 7.43 inches; minimum, 6.90 inches.

Ten springs of the lot closed solid 100 times—Permanent set: Maximum, 0.08 inch; minimum, 0.01 inch.

	Required.	Results.
Free height		Maximum, 7.33 inches; minimum, 6.88 inches.
Solid height	Not over 2 inches	Maximum, 1.87 inches; minimum, 1.78 inches.
Load at height of 4.562 inches	Not under 60 pounds	Maximum, 68 pounds; minimum, 56 pounds.
Outside diameter, solid	Not over 2.15 inches	Maximum, 2.15 inches; minimum, 2.14 inches.
Inside diameter, free	Not under 1.75 inches	1.75 inches.
Final free height		Maximum, 7.32 inches; minimum, 6.86 inches.

Three springs below 60 pounds at height of 4.562 inches. Free height not prescribed.

COMPRESSIVE TEST OF 71 SPRINGS FOR 6-INCH DUMMY PROJECTILES.

Free height: Maximum, 2.22 inches; minimum, 2.13 inches.

Height after being closed down solid for 48 hours—Free height: Maximum, 2.19 inches; minimum, 2.10 inches.

Twenty springs of the lot closed solid 100 times without permanent set.

	Required.	Results.
Free height	2.125 inches	Maximum, 2.19 inches; minimum, 2.10 inches.
Load at height of 1.535 inches	16.55 pounds	Maximum, 17 pounds; minimum, 15.25 pounds.
Load at height of 1.276 inches	23.8 pounds	Maximum, 23.5 pounds; minimum, 21.75 pounds.
Height when solid	1.276 inches	Maximum, 1.15 inches; minimum, 1.10 inches.
Outside diameter	0.375 inches	0.375 inches.
Final free height	2.125 inches	Maximum, 2.19 inches; minimum, 2.10 inches.

Measurements of lid springs for firing circuits, 12-inch M. C., Model of 1896 M111.

	Required.	Results.
Diameter of steel wire	0.040 inch	Maximum, 0.040 inch; minimum, 0.040 inch.
Number of coils	8	Maximum, 8; minimum, 8.
Length of spring	0.45 inch	Maximum, 0.47 inch; minimum, 0.38 inch.
Length of prong	0.10 inch	Maximum, 0.12 inch; minimum, 0.08 inch.
Outside diameter not more than	0.24 inch	Maximum, 0.234 inch; minimum, 0.230 inch.
Inside diameter not less than	0.14 inch	Maximum, 0.150 inch; minimum, 0.144 inch.

COMPRESSIVE TESTS OF 15 SPRINGS FOR 10-INCH DUMMY PROJECTILES.

Free height: maximum, 2.12 inches; minimum, 2.04 inches.

Height after being closed down solid 48 hours—Free height: Maximum, 2.08 inches; minimum, 1.96 inches.

Four springs of the lot closed solid 100 times. Permanent set: Maximum, 0.03 inch; minimum, 0.01 inch.

	Required.	Results.
Free height	2.03 inches	Maximum, 2.09 inches; minimum, 1.96 inches.
Load at height of 1.625 inches	58.7 pounds	Maximum, 64 pounds; minimum, 48 pounds.
Load at height of 1.32 inches	103 pounds	Maximum, 108.5 pounds; minimum, 92.5 pounds.
Height when solid	1.32 inches	Maximum, 1.11 inches; minimum, 1.04 inches.
Outside diameter	0.75 inch	0.75 inch.
Final free height	2.03 inches	Maximum, 2.07 inches; minimum, 1.95 inches.

Six springs above 58 pounds at height of 1.625 inches.
Nine springs above 103 pounds at height of 1.32 inches.
Four springs above 2.03 inches in height.

COMPRESSIVE TESTS OF 65 SPRINGS FOR 5-INCH DUMMY PROJECTILES.

Free height: Maximum, 0.78 inch; minimum, 0.76 inch.

Height after being closed down solid for 48 hours—Free height: Maximum, 0.78 inch; minimum, 0.75 inch.

Sixteen springs of the lot closed solid 100 times without permanent set.

	Required.	Results.
Free height	0.76 inch	Maximum, 0.78 inch; minimum, 0.76 inch.
Load at height of 0.56 inch	6.36 pounds	Maximum, 7.75 pounds; minimum, 6.25 pounds.
Load at height of 0.42 inch	10.8 pounds	Maximum, 16 pounds; minimum, 11 pounds.
Height when solid	0.42 inch	Maximum, 0.42 inch; minimum, 0.42 inch.
Outside diameter	0.31 inch	Maximum, 0.31 inch; minimum, 0.31 inch.
Final free height	0.76 inch	Maximum, 0.78 inch; minimum, 0.76 inch.

One spring below 6.50 pounds at height of 0.56 inch.
Fifteen springs above 13 pounds at height of 0.42 inch.
Twelve springs above 0.77 inch in height.

COMPRESSIVE TESTS OF 41 SPRINGS FOR 6-INCH DUMMY PROJECTILES.

Free height: Maximum, 2.22 inches; minimum, 2.10 inches.

Height, after being closed down solid for 48 hours—Free height: Maximum, 2.17 inches; minimum, 2.06 inches.

Ten springs of the lot closed solid 100 times without permanent set.

	Required.	Results.
Free height	2.125 inches	Maximum, 2.17 inches minimum, 2.06 inches.
Load at height of 1.535 inches	16.55 pounds	Maximum, 17 pounds; minimum, 14 pounds.
Load at height of 1.276 inches	23.8 pounds	Maximum, 23.25 pounds; minimum 21 pounds.
Height when solid	1.276 inches	Maximum, 1.15 inches; minimum, 1.12 inches.
Outside diameter	0.375 inch	0.375 inch.
Final free height	2.125 inches	Maximum, 2.17 inches; minimum, 2.06 inches.

Two springs above 16 pounds at height of 1.535 inches.

Two springs 23 pounds and over at height of 1.276 inches.

3 springs above 2.125 inches in height.

Measurements of brass wire springs for electrical circuit details, 12-inch mortar carriage, model of 1896, M111.

[Number of springs, 345.]

	Required.	Results.
Diameter of brass wire	0.0719 inch	Maximum, 0.075 inch; minimum, 0.072 inch.
Length of spring	5.5 inches	Maximum, 5.95 inches; minimum, 5.40 inches.
Outside diameter	0.625 inch	Maximum, 0.632 inch; minimum, 0.622 inch.
Large eye, inside diameter	0.75 inch	Maximum, 0.79 inch; minimum, 0.65 inch.
Small eye, inside diameter	0.375 inch	Maximum, 0.43 inch; minimum, 0.36 inch.

MISCELLANEOUS.

MISCELLANEOUS.

TENSILE TESTS OF 2 STEEL SPECIMENS FOR UNITED STATES NAVY.

The two specimens were special treated steel and furnished on contract No. 19563 for battleship *No. 39.*

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.	
			Load.	Stress (pounds per square inch).	Load.	Stress (pounds per square inch).
	Inch.	*Square inch.*	*Pounds.*		*Pounds.*	
227	0.5050	0.20	21,600	108,000	24,500	122,500
228	.5050	.20	21,900	109,500	24,800	124,000

Marks.	Elongation in 2 inches.		Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	Inch.	Per cent.	Inch.	Per cent.			
					Inch.	*Per cent.*	
227	0.41	20.5	[1] 0.30	0.11	0.31	62.3	Fine silky. Open seam in stem.
228	.38	19.0	[1] .25	.13	.32	59.8	Do.

[1] Inch section in which fracture occurred.

Tensile test of 2 specimens taken from a fractured cylinder, No. 123509 B2, for 4.7-inch howitzer carriage, model of 1908.

Marks.	Dimensions.		Sectional area.	Approximate elastic limit.		Tensile strength.	
	Width.	Thickness.		Total.	Pounds per square inch.	Total.	Pounds per square inch.
	Inch.	*Inch.*	*Square inch.*	*Pounds.*		*Pounds.*	
1	0.505	0.179	0.0904	10,812	119,600	12,648	139,910
1	.529	.180	.0952	11,016	115,710	13,158	138,210

Marks.	Elongation in 2 inches.		Elongation in inch sections.		Dimensions at fracture.	Contraction of area.	Appearance of fracture.
	Inch.	Per cent.	Inch.	Inch.			
					Inch.	*Per cent.*	
1	0.25	12.5	[1] 0.22	0.03	0.44 by 0.14	31.8	Dull silky.
2	.26	13.0	[1] .26	.00	.46 by .15	27.5	Do.

[1] Inch section in which fracture occurred.

TENSILE TESTS OF 2 SAMPLES OF STEEL.

Specimens received were about 2 feet long and ⅞ inch diameter. They were cut up into regular tension specimens and were marked as follows:

Marks.	Diameter.	Sectional area.	Elastic limit.		Tensile strength.		Elongation in 2 inches.	
			Load.	Stress (pounds per square inch).	Load.	Stress (pounds per square inch).	Inch.	Per cent.
	Inch.	*Sq. inch.*	*Pounds.*		*Pounds.*			
18 TA.......	0.505	0.20	11,100	55,500	17,700	88,500	0.60	30.0
18 TA.......	.505	.20	10,700	53,500	17,600	88,000	.59	29.5
18 TA.......	.505	.20	10,800	54,000	17,600	88,000	.59	29.5
18 TB.......	.505	.20	11,600	58,000	20,500	102,500	.47	23.5
18 TB.......	.505	.20	11,600	58,000	20,600	103,000	.46	23.0
18 TB.......	.505	.20	11,400	57,000	20,500	102,500	.48	24.0

Marks.	Elongation in inch sections.		Diameter at fracture.	Contraction of area.	Appearance of fracture.
	Inch.	*Inch.*	*Inch.*	*Per cent.*	
18 TA.......	[1]0.30	[1]0.30	0.34	54.6	Fine silky.
18 TA.......	[1].29	[1].30	.35	51.9	Do.
18 TA.......	[1].32	[1].27	.35	51.9	Do.
18 TB.......	[1].28	.19	.38	43.3	Do.
18 TB.......	[1].24	[1].22	.38	43.3	Do.
18 TB.......	.20	[1].28	.38	43.3	Do.

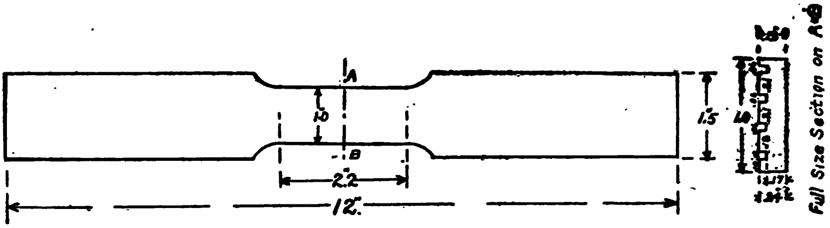
Tensile test of 6 galvanized malleable iron rings.

Number.	Inside diameter.	Diameter of wire.	Breaking strength.
	Inches.	*Inch.*	*Pounds.*
1..	1.26	0.16	451
2..	1.27	.17	427
3..	1.26	.17	920
4..	1.25	.17	710
5..	1.26	.17	869
6..	1.26	.17	641

TENSILE TEST OF A SECTION OF COPPER BAND TAKEN FROM A 12-INCH PROJECTILE AFTER SEATING.

Length of specimen over all, 12 inches.

Width of specimens: 1.50 inches with a reduced section of 1 inch by 2.20 inches in length at middle.



	Sectional area.	Tensile strength.		Elongation in 2 inches.	
		Total.	Pounds per square inch.	Inch.	Per cent.
	Sq. inch.	*Pounds.*			
Required	....	....	28,000	....	30.0
Results	0.238	8,466	35,570	0.80	40.0

	Elongation in inch sections.		Dimensions at fracture.	Contraction of area.	Appearance of fracture.
	Inch.	Inch.			
			Inch.	*Per cent.*	
Required	....	....	....	35.0	
Results	[1] 0.50	0.30	0.73×0.15=0.1095	54.0	Dark salmon.

[1] Inch section in which fracture occurred.

TENSILE TEST OF 2 SAMPLES OF GAS CHECK PAD COVERING MATERIAL FOR SANDY HOOK PROVING GROUND.

Samples marked XI and XII.

Four tests were made from each sample, two one way of the material and two the other way.

Length of sample over all, 6 inches.

Length between fixtures, 2 inches.

Width of samples, 1 inch.

Marks.	Direction tested.	Number of threads.	Width of sample.	Tensile strength.
			Inch.	*Pounds.*
X I	One way	30	1	104
X I	.....do	30	1	109
X I	Other way	42	1	106
X I	.....do	42	1	111
X II	One way	29	1	79
X II	.....do	29	1	74
X II	Other way	39	1	144
X II	.....do	39	1	134

Hardness taken by the Shore scleroscope on twist drills of a number of makes.

Size of drill.	Number of drills.	Marks on drills.	Kind of steel.	Kind of shank.	Shore scleroscope hardness.
No. 22	12	22	Carbon	Straight	40 to 60
No. 23	12	23	do	do	50 to 62
3/16-inch	6	3/16 H. S.	High speed	do	55 to 65
Do	12	3/16 H. S.	do	do	55 to 60
7/32-inch	3	7/32 H. S.	do	do	53 to 57
41/64-inch	1	L.	do	Taper	25 to 30
41/64-inch	1	L.	do	do	51 to 67
1 1/8-inch	1	L.	do	do	70 to 77
1 31/64-inch	1	L.	do	do	70 to 75
Do	1	L.	do	do	70 to 75
1 1/16-inch	1	C.		do	60 to 80
11/16-inch	1	C.		do	60 to 72
31/32-inch	1	L.	High speed	do	50 to 62
Do	1	L.	do	do	55 to 62
3/4-inch	1	L.	do	do	50 to 67
No size given	1	L.	do	do	52 to 68
Do	1	L.	do	do	52 to 62
7/8-inch	1	L.	do	do	50 to 60
Do	1	L.	do	do	50 to 65
31/32-inch	1	L.	do	do	50 to 60
Do	1	L.	do	do	52 to 70
1 1/4-inch	1	L.	do	do	64 to 75
1 31/64-inch	1	L.	do	do	60 to 77
1 5/64-inch	1	M.		do	65 to 83
1 3/16-inch	1	L.	High speed	do	70 to 82
1 31/64-inch	1	C.	do	do	82 to 87
1 3/64-inch	1	U.	do	do	80 to 88

BREECH BUSHING FROM 14-INCH GUN.

EXAMINATION OF BREECH BUSHING FROM 14-INCH GUN, MODEL OF 1907, M1, NO. 2.

PHYSICAL TEST.

The physical requirements for this forging were: Tensile strength, 100,000 pounds; elastic limit, 70,000 pounds; elongation, 16 per cent; contraction, 30 per cent.

Two specimens were taken from each of the radial, tangential, and longitudinal directions, as indicated on photographs Nos. 7, 8, 9, and 10. Photographs Nos. 9 and 10 show the location and extent of the crack.

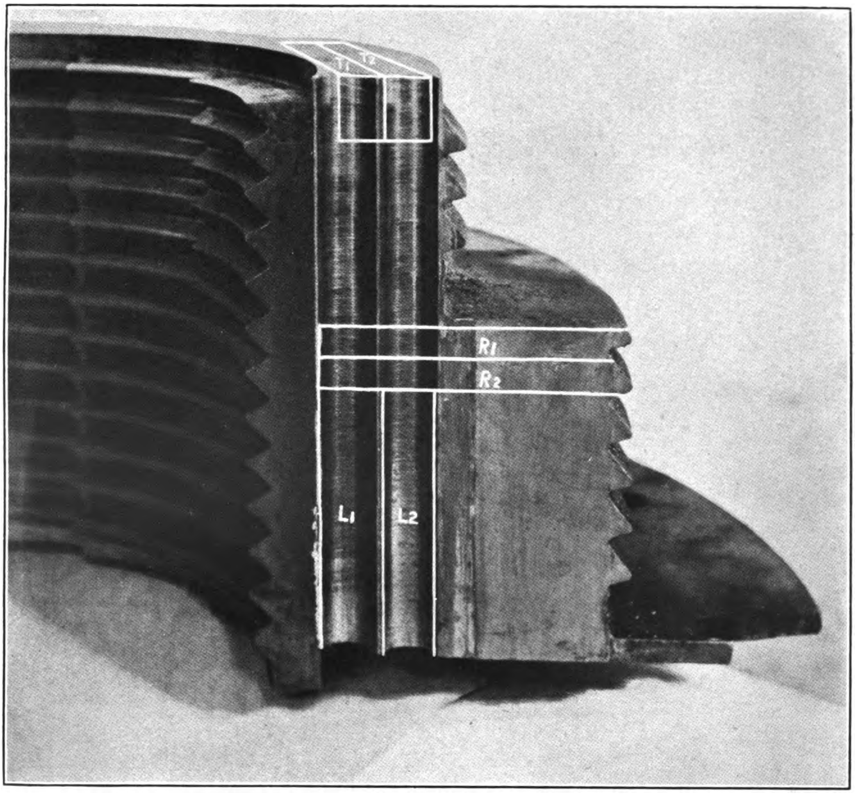
The results obtained were as follows:

Marks.	Tensile strength (pounds per square inch).	Elastic limit (pounds per square inch).	Elongation.	Contraction.	Remarks.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	
T 1	98,500	72,000	18.5	46.2	Tangential.
T 2	103,500	73,500	16.5	30.7	
R 1	91,500	73,000	4.5	9.5	Radial.
R 2	98,500	72,500	12.5	27.4	
L 1	105,500	75,000	23.0	57.2	Longitudinal.
L 2	101,500	74,000	21.0	54.6	

Specimen R 1 broke at a slag spot, and a comparison with R 2, which was taken from almost the same place, shows a decided difference in physical properties.

The chemical analysis was as follows:

	Per cent.
C	0.458
Mn	.42
Si	.10
S	.047
P	.028
Ni	3.13
Cr	1.10



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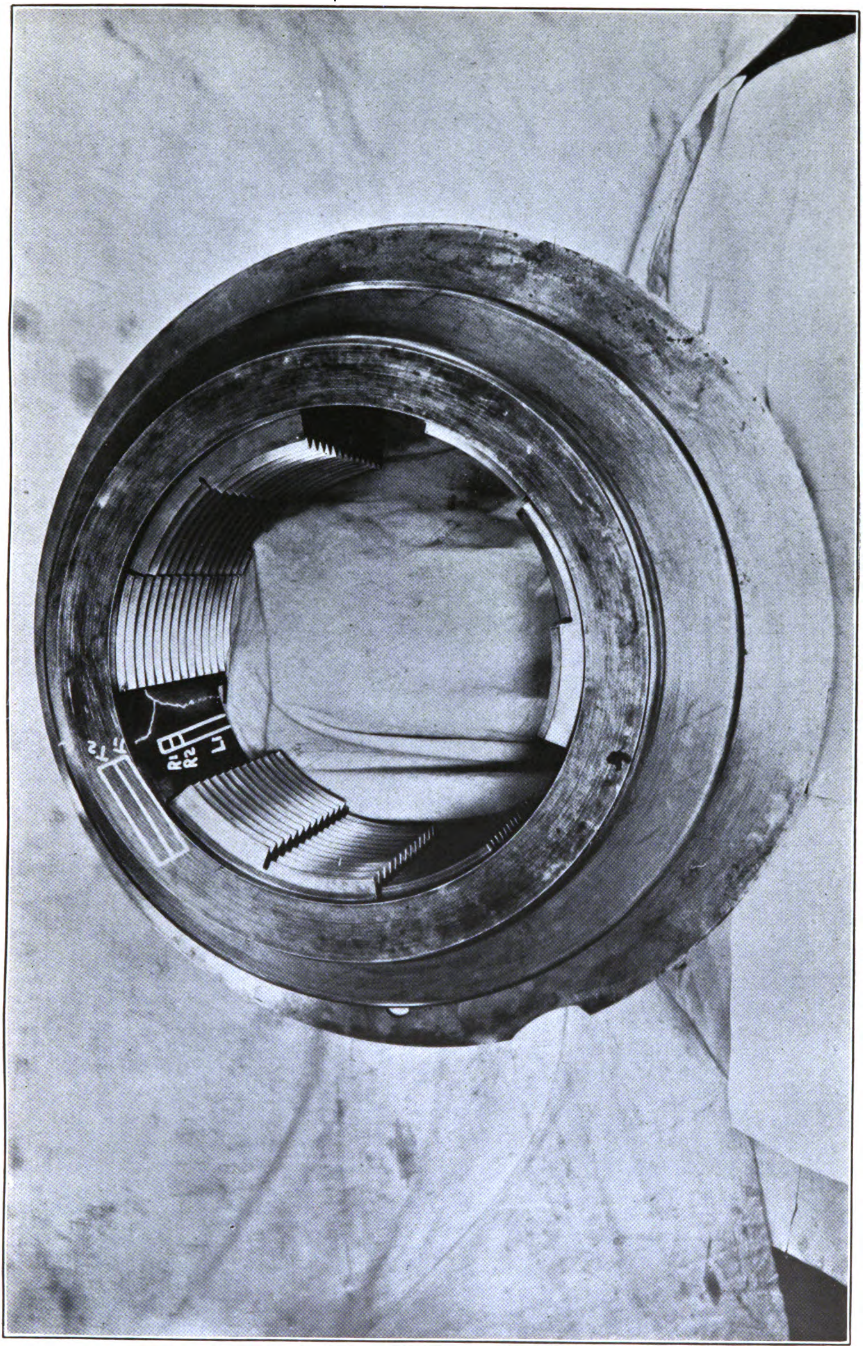

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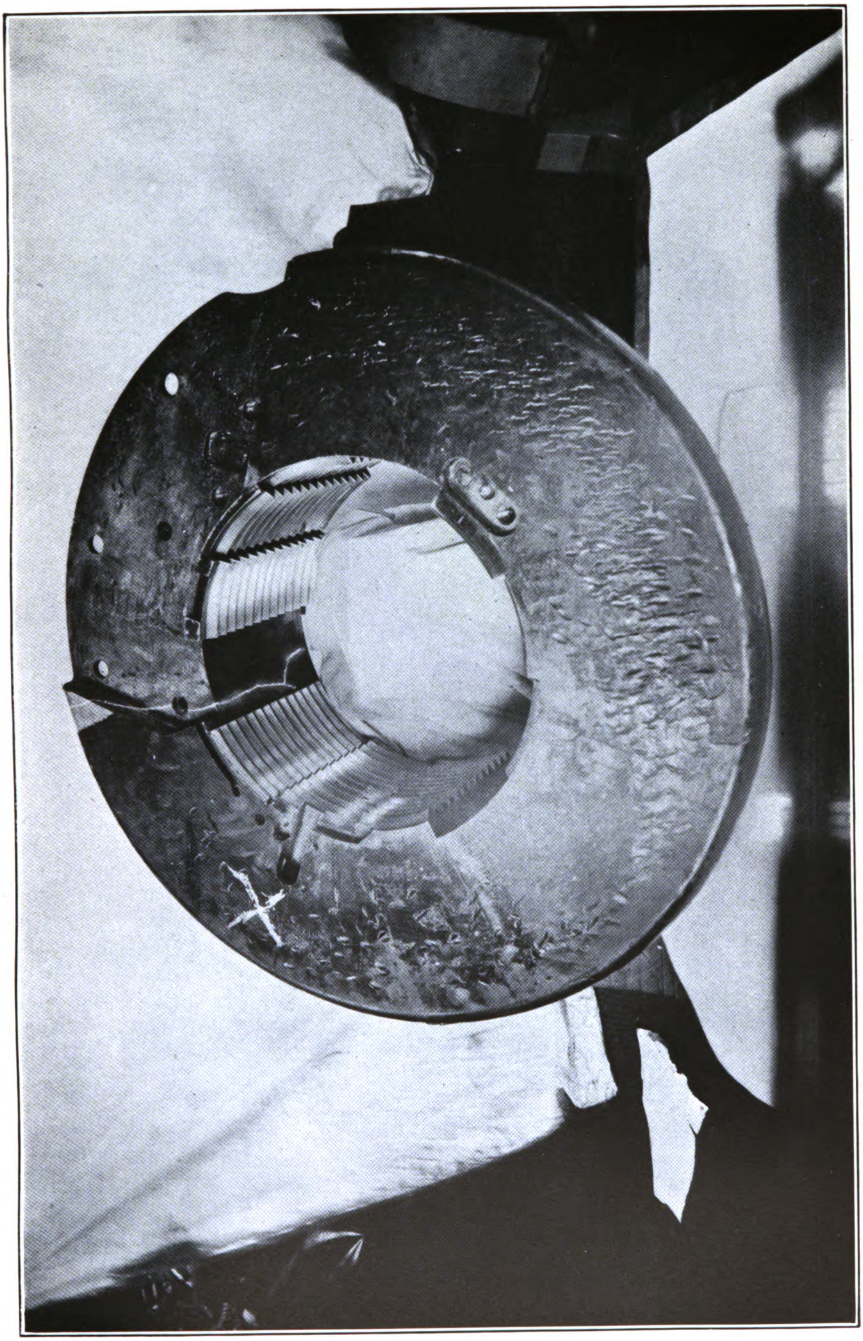
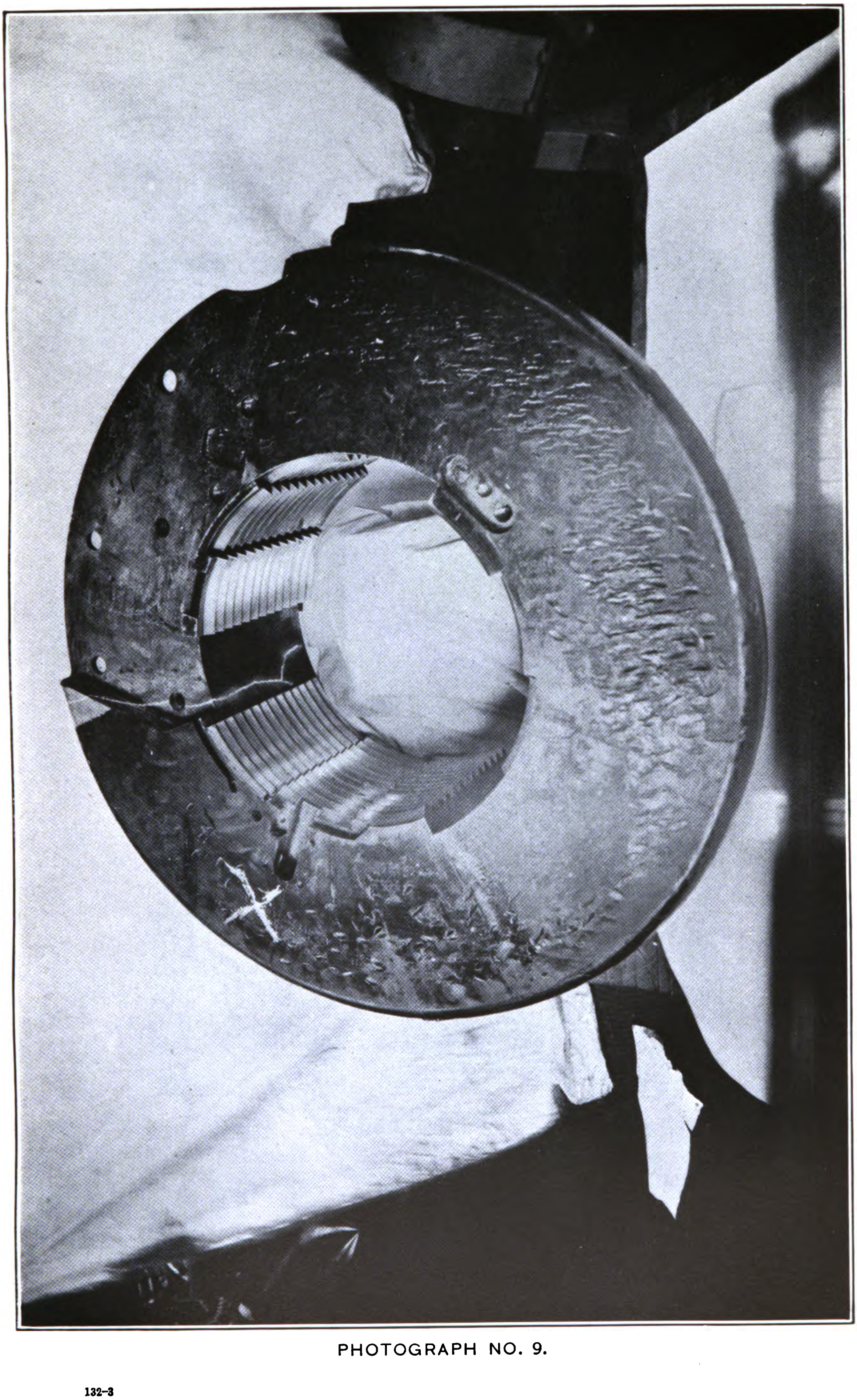


PHOTOGRAPH NO. 9.

132-3



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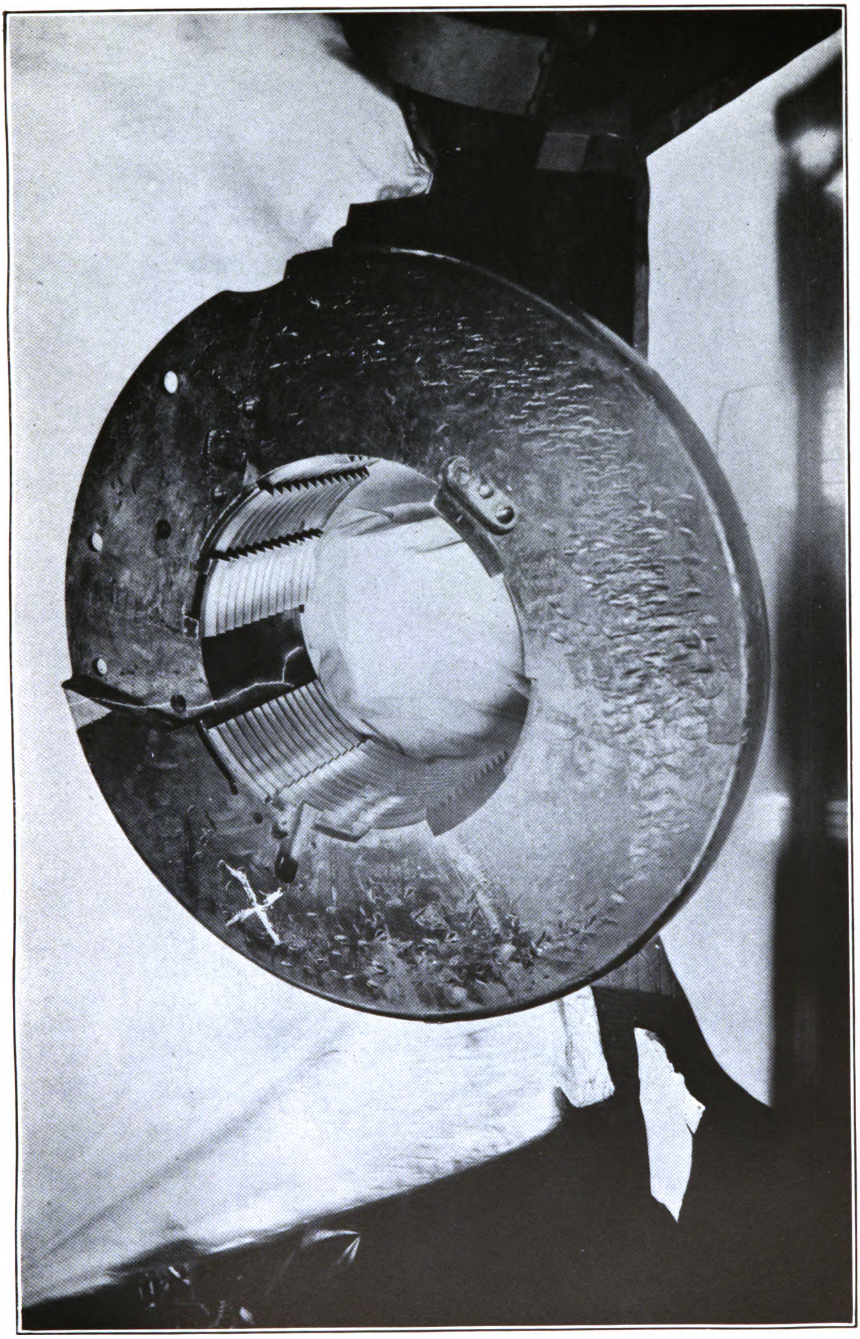
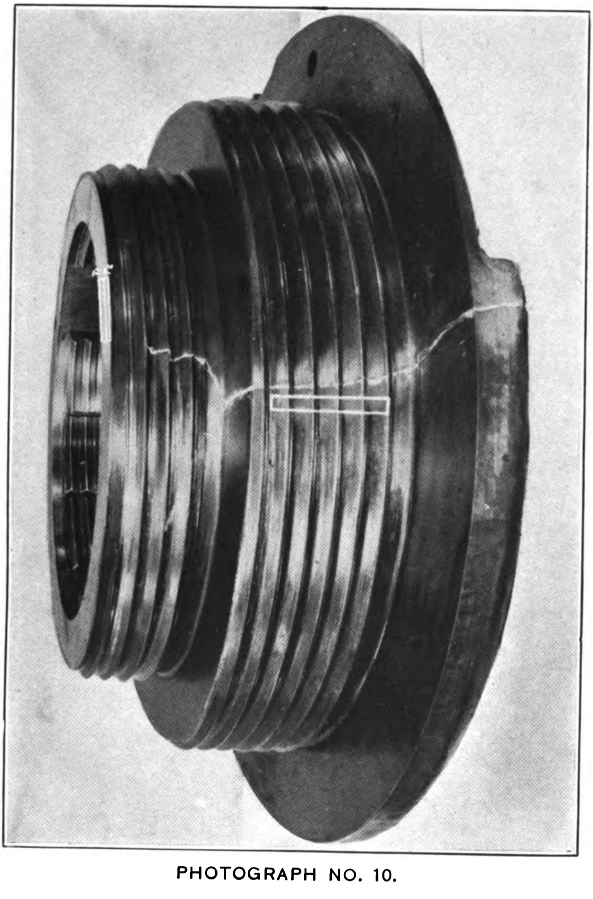


PHOTOGRAPH NO. 9.

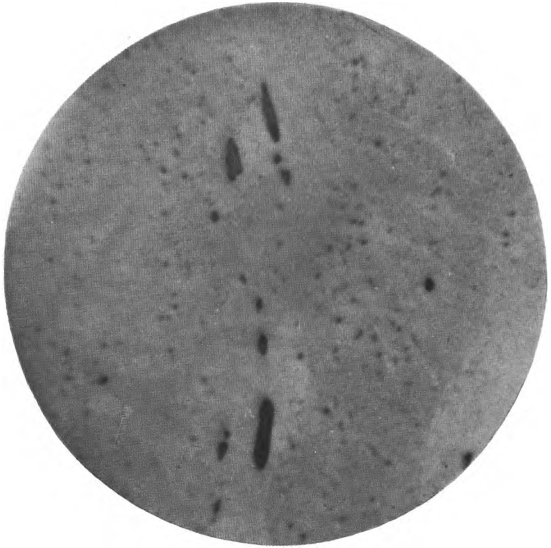
132—3



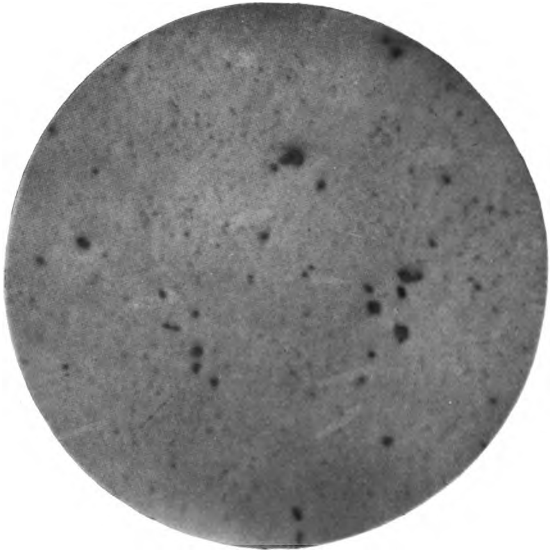
PHOTOGRAPH NO. 10.

132-4

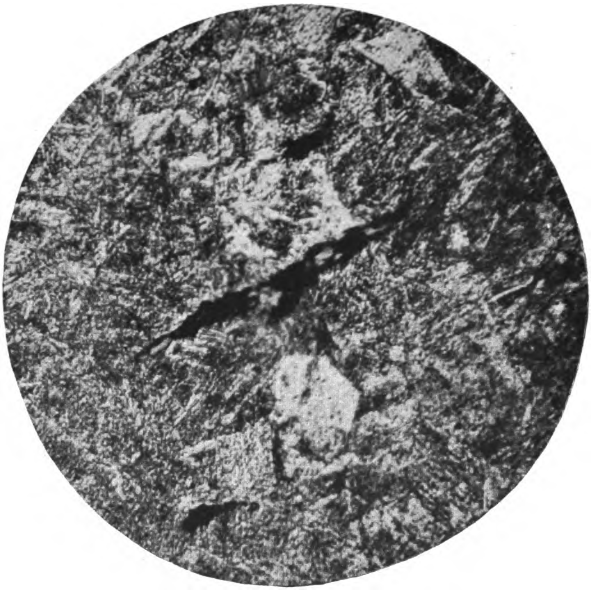
133-1



PHOTOGRAPH NO. 1. TANGENTIAL SECTION. (X50.)

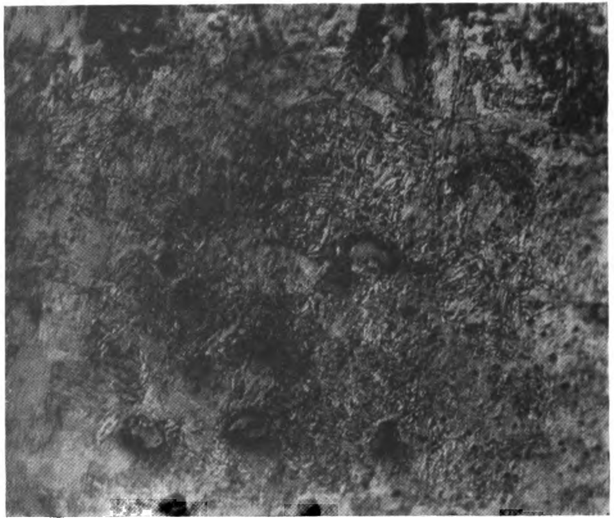


PHOTOGRAPH NO. 2. LONGITUDINAL SECTION. (X50.)

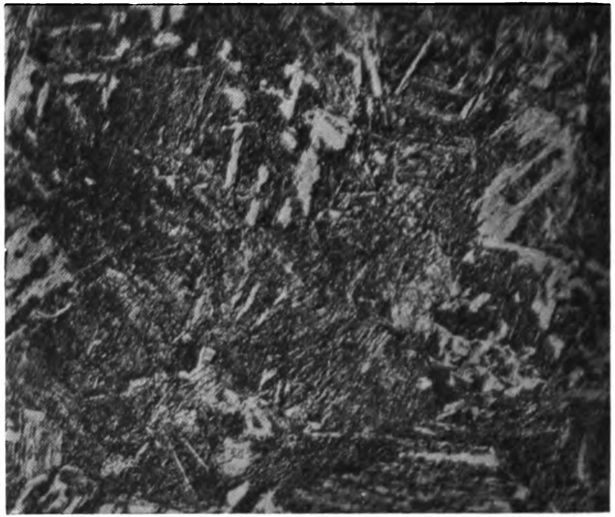


PHOTOGRAPH NO. 3. TANGENTIAL SECTION. (X75.)

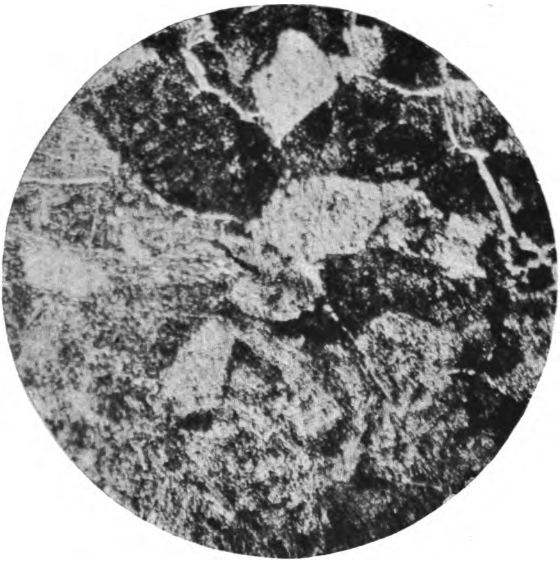
133-2



PHOTOGRAPH NO. 4. RADIAL SECTION. (X75.)



PHOTOGRAPH NO. 5. RADIAL SECTION. (X75.)



PHOTOGRAPH NO. 6. TANGENTIAL SECTION. (X75.)

133-4

METALLOGRAPHIC EXAMINATION.

For microscopic examination six specimens, 4 by 1 inches, two each from longitudinal, tangential, and radial positions, were polished and etched on two sides with 4 per cent nitric acid solution. There were slight evidences of minor segregation and no evidences of original ingot structure.

One of the test specimens from each of the three positions, after having been broken, was polished and examined microscopically. Each showed more than the usual amount of slag and in fairly large masses, drawn out in the direction of forging, and with strong tendency to be drawn out in lines. Photograph No. 1 shows this tendency, and photograph No. 2 shows a section cut normal to it. In the etched specimens the same phenomena is evident, as shown in photographs Nos. 3 and 4.

The etched specimens show very strongly two facts—overheating and minor local segregation. The overheating is shown in (*a*) the strong tendency toward crystallization with the elongated needles of ferrite reaching out through the ground mass of the material, as shown in photograph No. 5; (*b*) the pearlitic condition of the ground mass, and (*c*) the coarsely granulated structure shown in the lower portion of photograph No. 6.

Local segregation has been found in each section, the most pronounced being that shown in photograph No. 6, where we have two contiguous structures of entirely different character, one distinctly granulated, the other more homogeneous. In the other sections characteristic differences of structure were observable, but which were not so well adapted for photographic representation.

While no direct connection between fracture and structure has been established it is evident that the metal is of inferior character (1) on account of the slag which is present, (2) the unsatisfactory heat treatment, and (3) the local segregation.

IMPACT TESTS.

TEST OF CHARPY IMPACT MACHINE.

In order to determine whether the Charpy machine could reveal brittle metal where the regular tensile test failed to do so, the following experiment was made.

Pieces of a 14-inch gun jacket were taken, and the metal was tested in the original condition, and after drawing at 750° C., 700° C., 600° C., and 500° C., respectively, for half an hour, cooling in the furnace. Static tensile, Charpy impact and hardness tests were made, after which micrographs were taken.

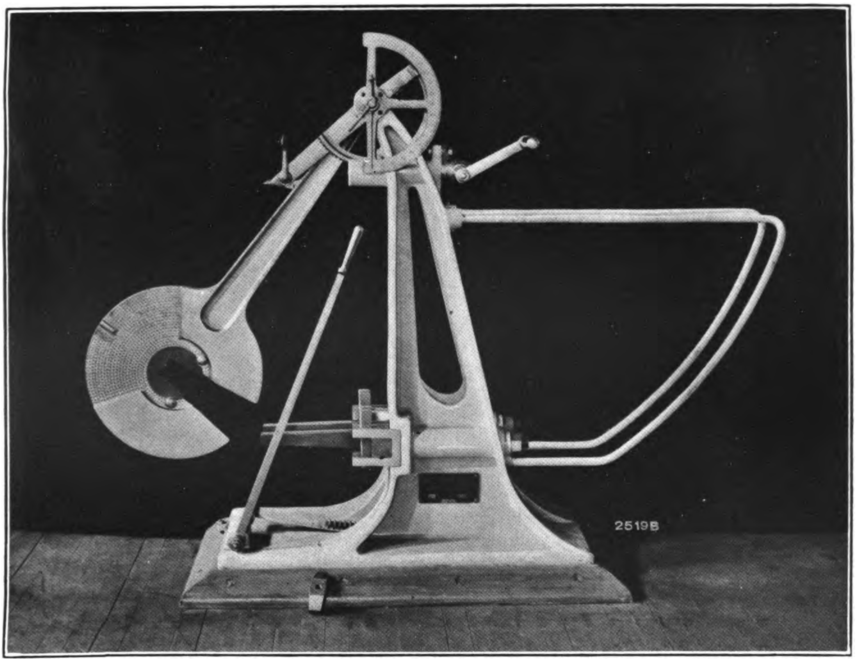
Pieces of the original metal were then heated to 50° C. above the Ac_1 point (788° C.), quenched in oil, and then drawn at 650° C., 600° C., 550° C., and 500° C., respectively, for half an hour, cooling in the furnace. The following results were obtained:

Heat treatment.	Original steel.	Reheat to—				Quench 50° C. above Ac_1. Reheat half an hour at—			
		750° C.	700° C.	600° C.	500° C.	650° C.	600° C.	550° C.	500° C.
		Hold half an hour.				Cool in furnace.			
Specimen mark..	13T15-0	13T15-1	13T15-2	13T15-3	13T15-4	13T15-D	13T15-E	13T15-F	13T15-G
Charpy..........	51.5	147.9	118.8	140.8	134.0	119.7	186.1	212.0	170.0
	50.6	133.4	148.1	161.7	178.2	140.8	186.1	176.9	204.2
	26.2	195.6	148.1	162.0	147.8	134.8	178.2	212.0	155.8
	64.1	151.0	173.0	139.0	154.8	150.3	186.6	204.8	184.2
Average...	48.1	158.0	147.0	151.0	154.0	136.4	184.3	201.4	178.6
Elastic limit.....	50,000	47,000	45,500	49,000	50,000	64,500	70,500	78,500	83,500
Tensile strength.	101,000	91,500	90,500	99,500	100,500	104,500	113,500	126,000	134,500
Elongation......	20.0	22.5	25.0	21.0	20.0	20.0	20.5	18.0	16.0
Contraction......	27.4	34.0	49.1	40.3	37.2	54.6	46.2	46.2	37.2
Ball hardness....	187	159	162	187	187	....	....	....	....

Hardness numbers and micrographs were not taken of the specimens which were quenched in oil (D, E, F, and G).

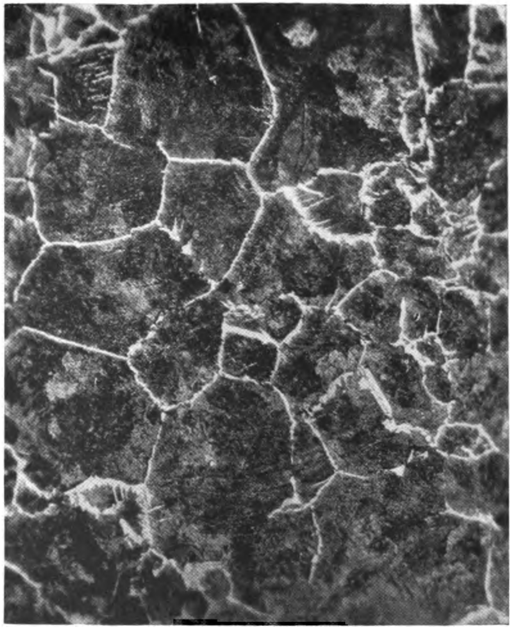
From the table it is seen that the impact strength of the original steel was very low. Specimens 13T15-3 and 13T15-4 give the same hardness number (187), practically the same tensile strength, elastic limit, and elongation, yet the impact strength has been increased to three times that of the original steel.

In this case at least the Charpy machine indicated defective metal which the tensile test failed to detect.

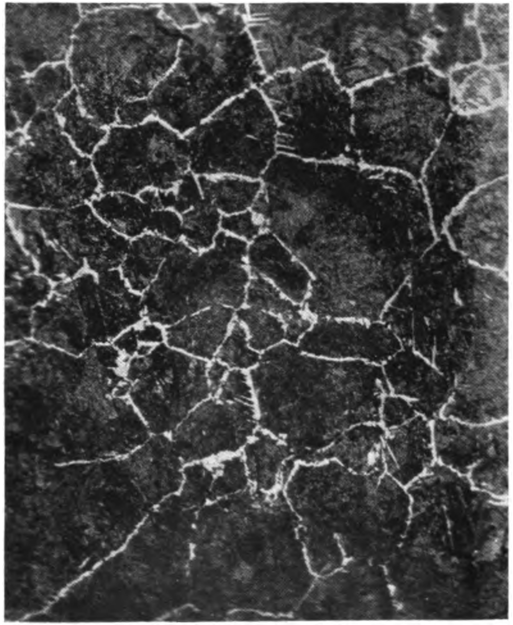


CHARPY IMPACT MACHINE.

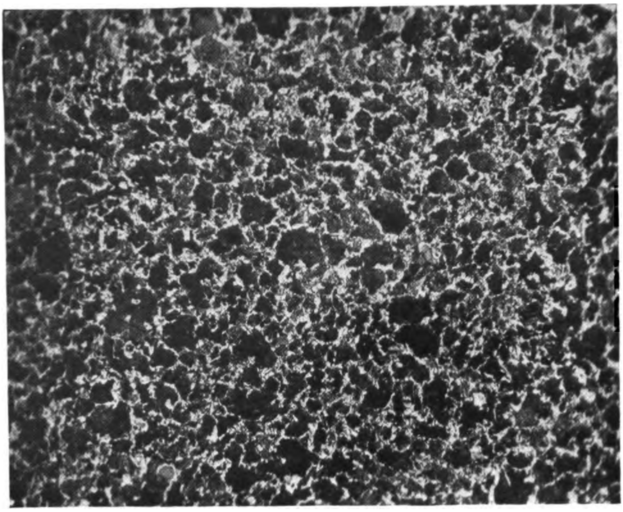
136–1



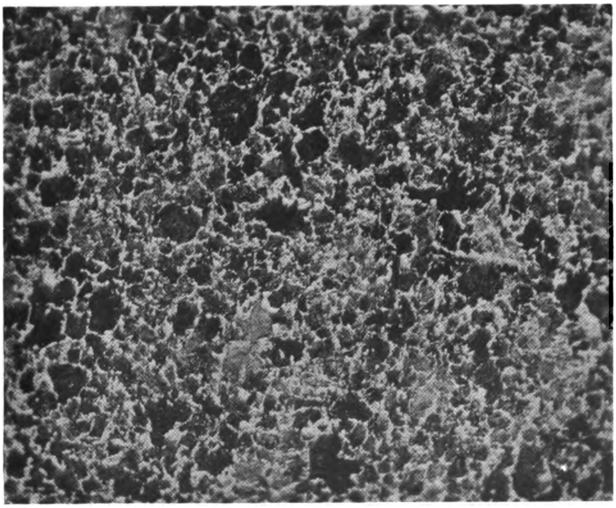
13T15–O–4. (X75.)



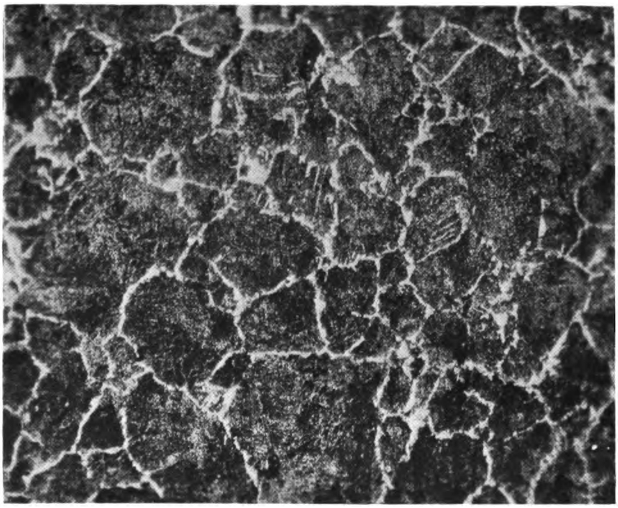
13T15–O–3. (X75.)



13T15-1-2. (X75.)



13T15-1-3. (X75.)



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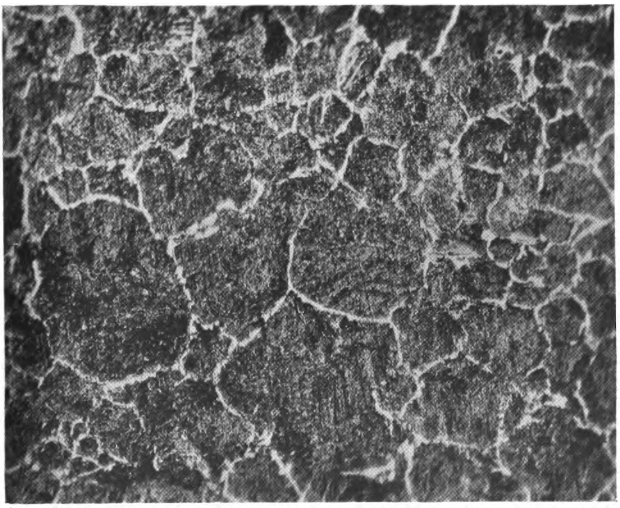

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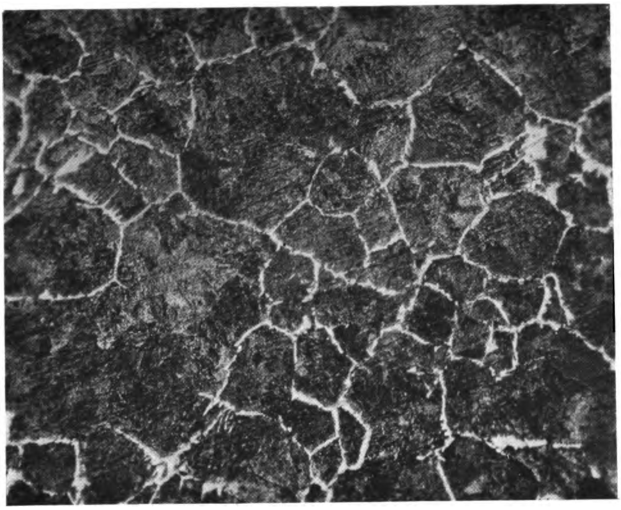
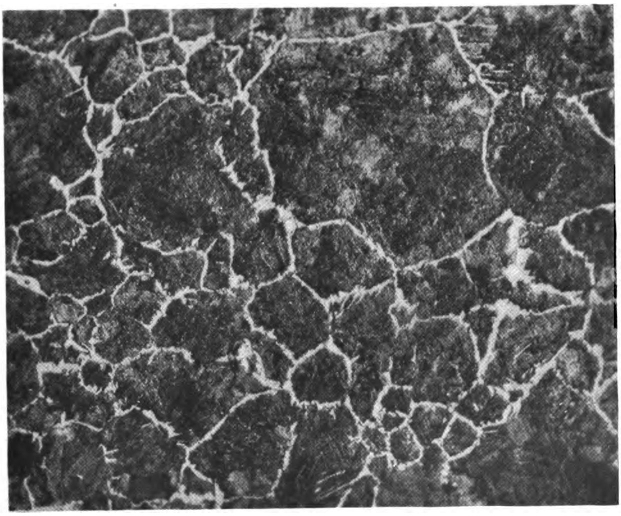
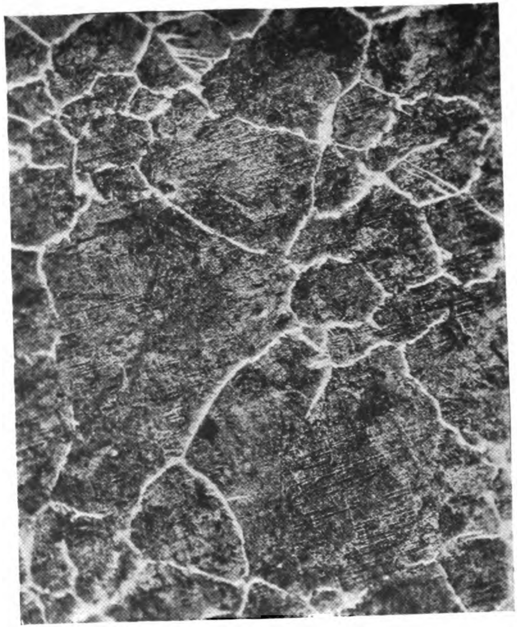


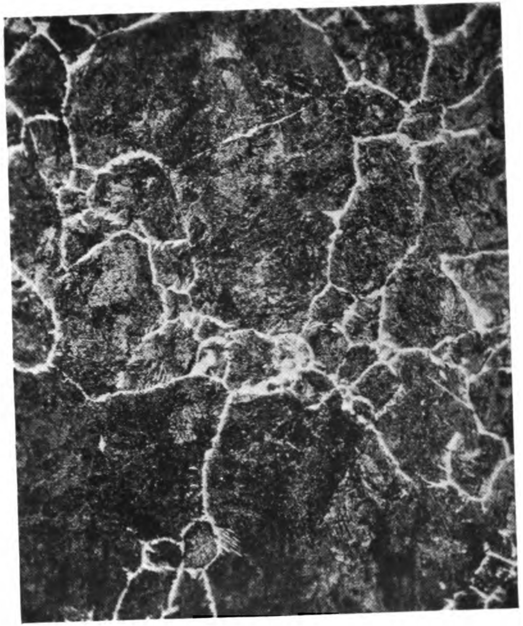
13T15-3-4. (X75.)



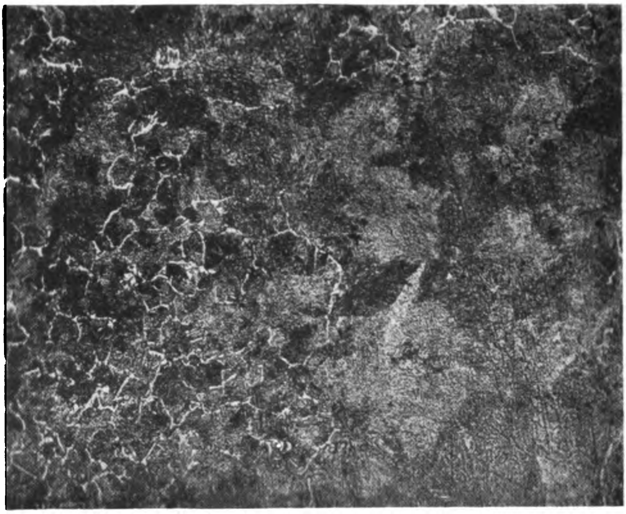
(13T15-3-1. (X75.)



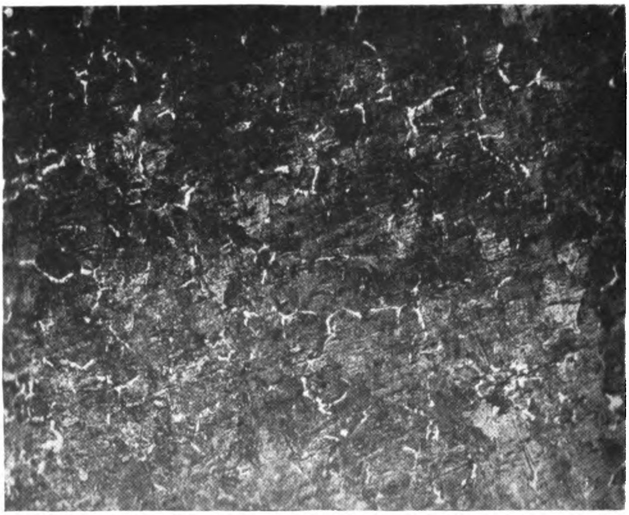
13T15-4-1. (X75.)



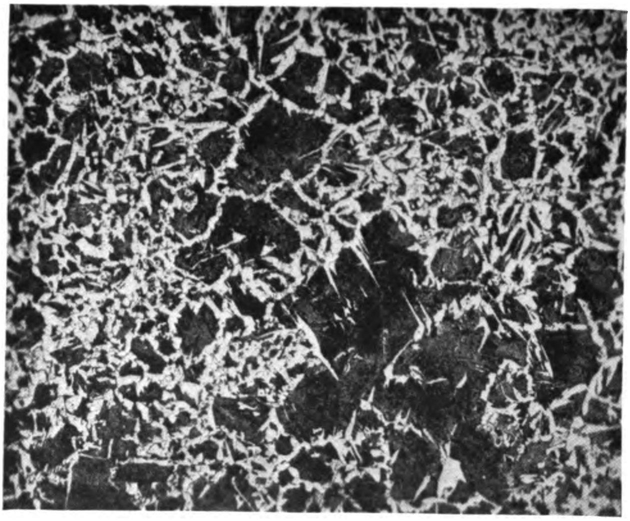
13T15-4-2. (X75.)



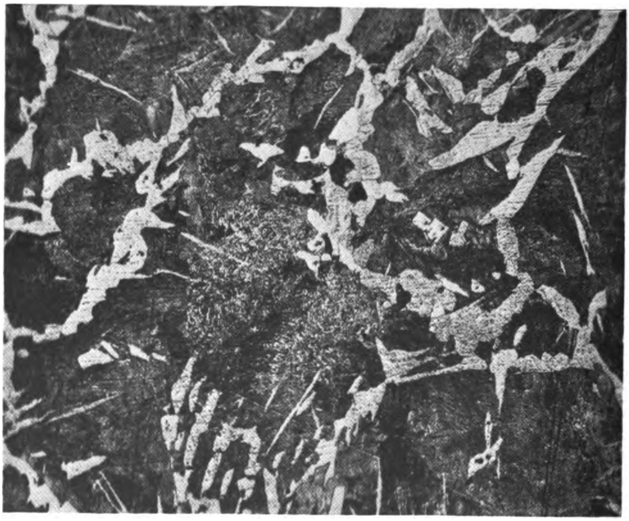
PHOTOGRAPH NO. 1. (X75.)



PHOTOGRAPH NO. 2. (X75.)



PHOTOGRAPH NO. 3. (X75.)



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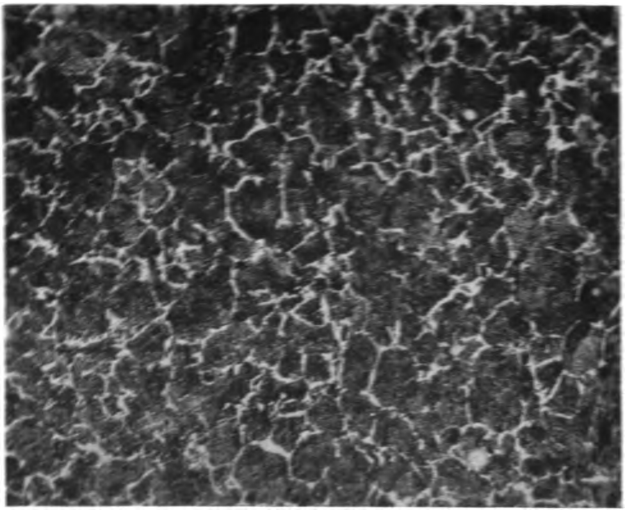
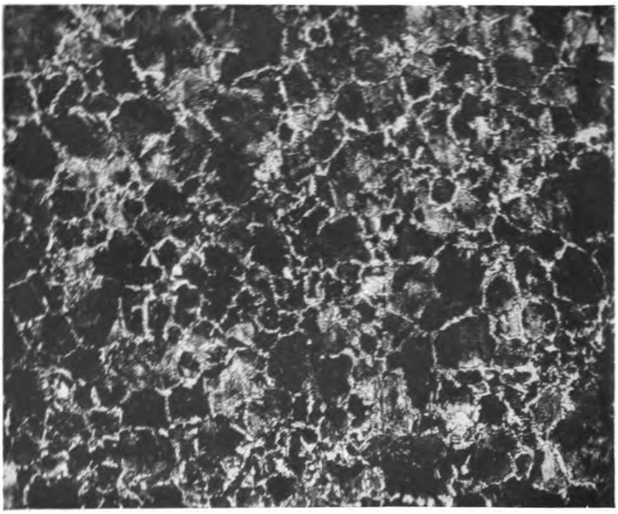
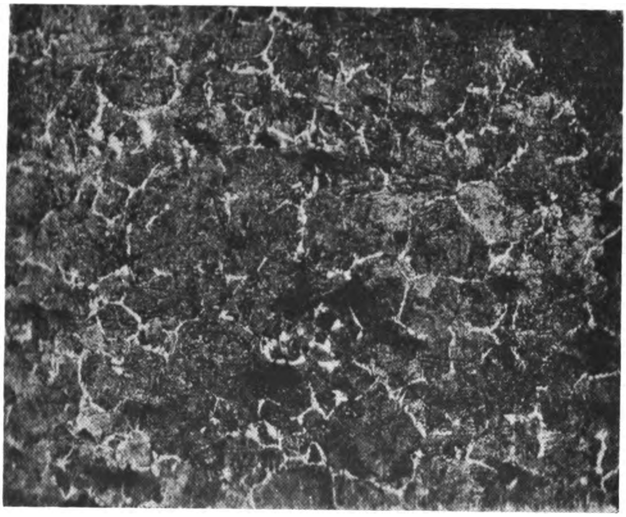


PHOTOGRAPH NO. 5. (X75.)



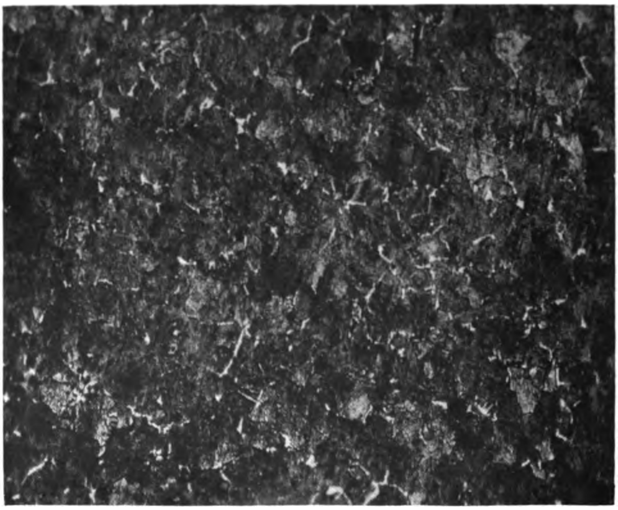
PHOTOGRAPH NO. 6. (X75.)

137-3

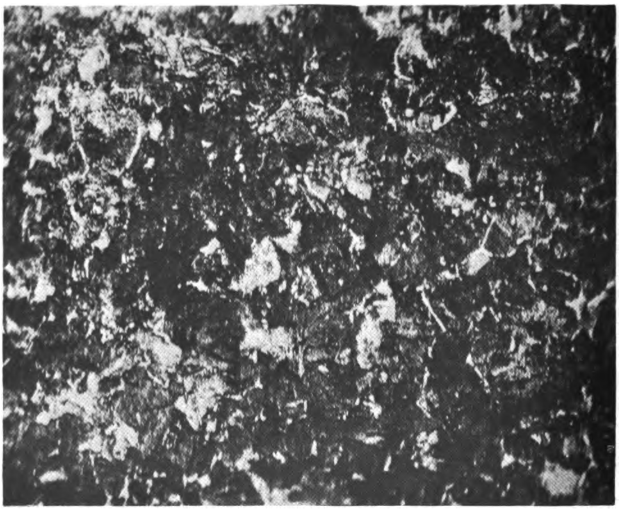


PHOTOGRAPH NO. 7. (X75.)

137-4



8-2. (X75.)



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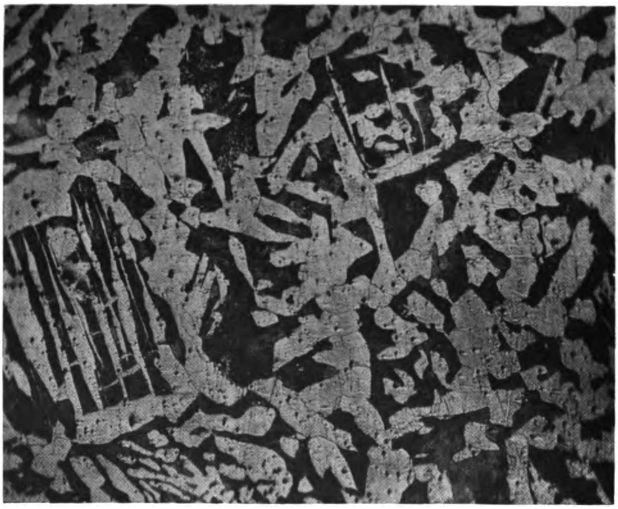
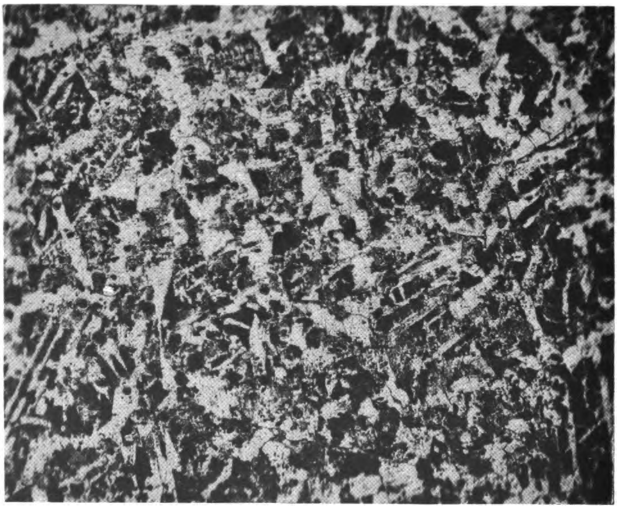
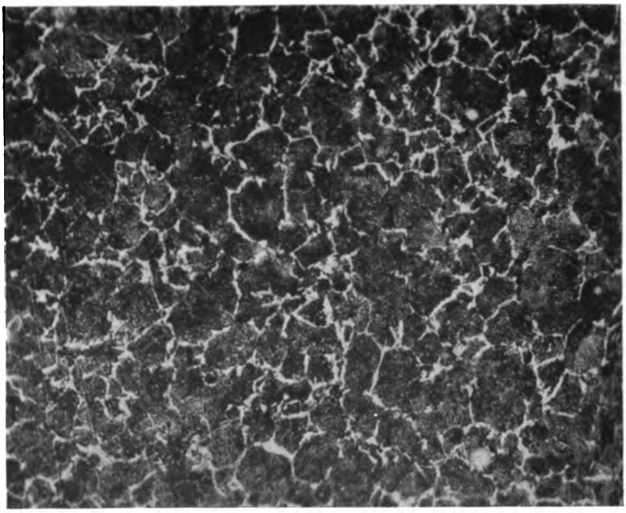


D. (X75.)



T. (X75.)

137-6



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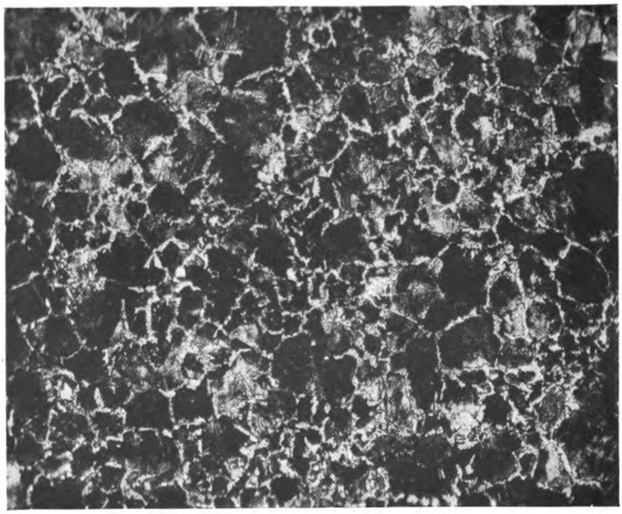

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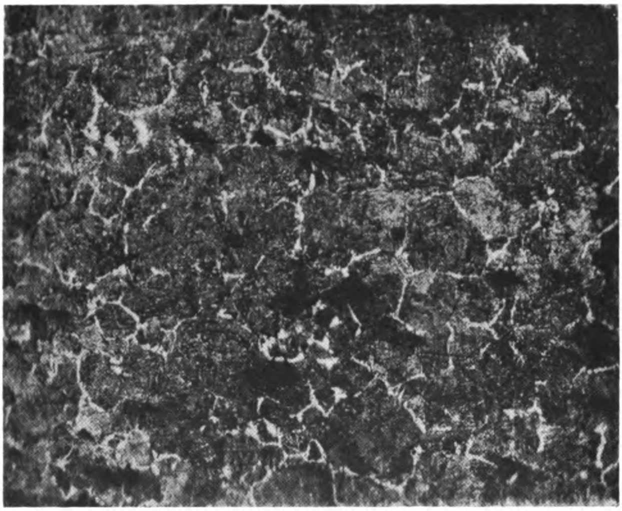
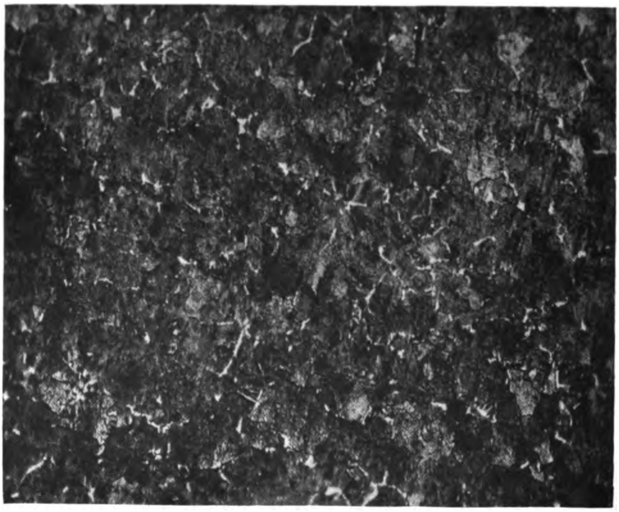
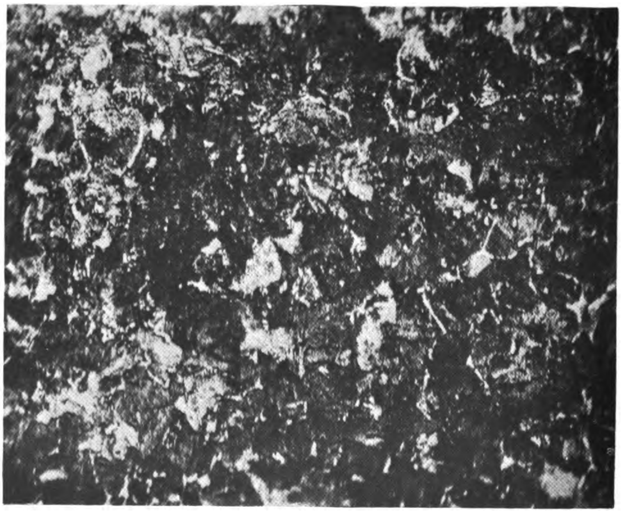


PHOTOGRAPH NO. 7. (X75.)

137—4

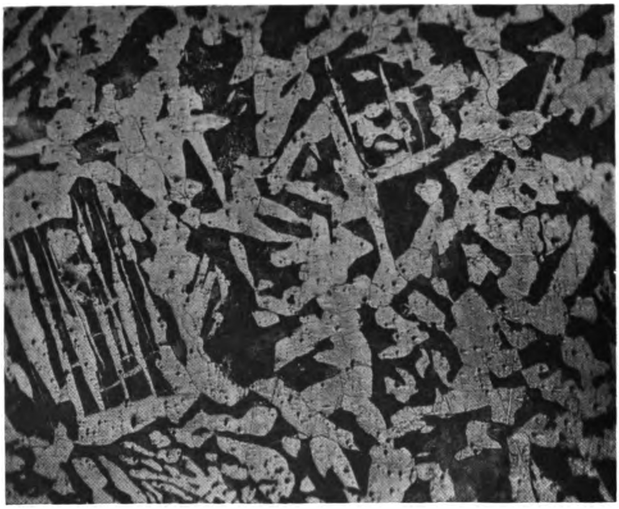


8-2. (X75.)

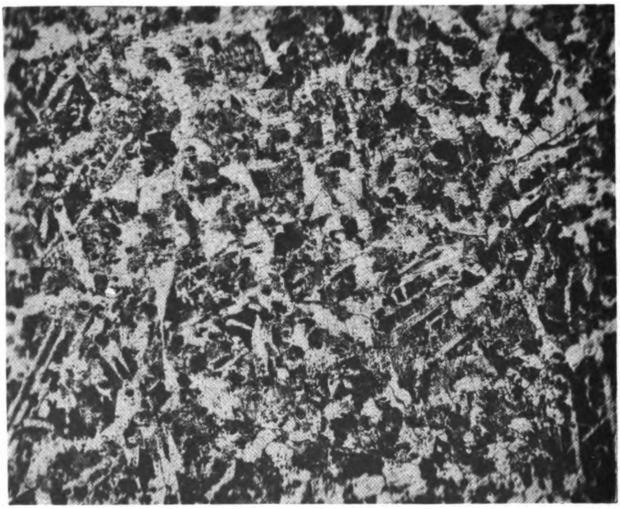


8-3. (X75.)

137-5

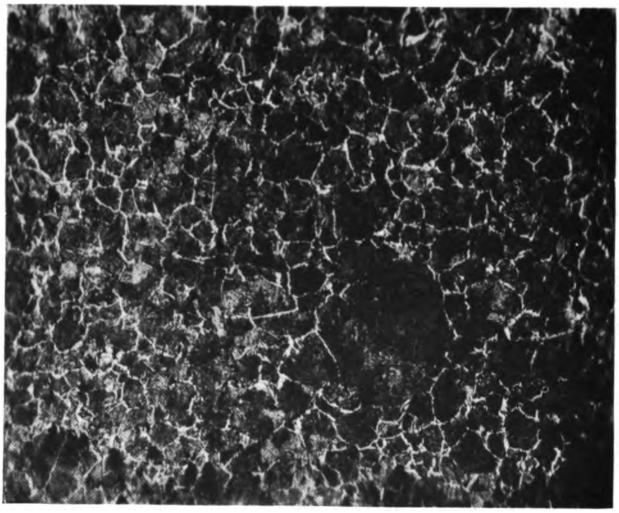


D. (X75.)

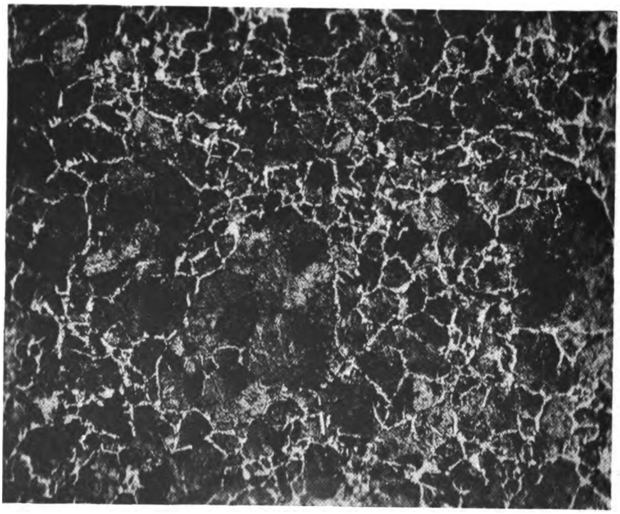


T. (X75.)

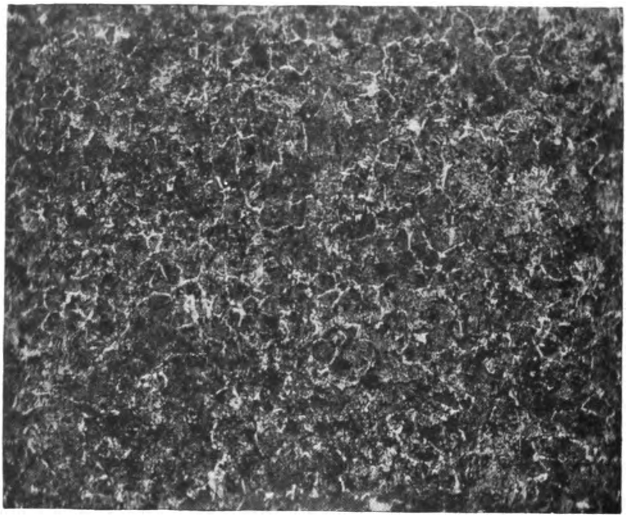
137-6



HD1. (X75.)



HD2-4. (X75.)



HD2-2. (X75.)

The micrographs of 13T15–0, 13T15–3, and 13T15–4 do not differ materially in grain size, but this could hardly be expected as the metal was not heated above Ac_1. Specimen 13T15–1 was heated above Ac_1 and there has been a refining of the grain, accompanied by a decrease of strength and an increase of ductility. Micrographs were taken of the specimens giving the highest and lowest impact strength in each of the five tests. From these it is seen that the brittleness is not a function of the grain size alone. It is probable that the weak impact strength in the original steel was due to internal stresses which were relieved by the subsequent annealing in specimens 13T15–3 and 13T15–4. The original steel bar has the appearance of having cooled slowly from a high temperature before quenching.

An investigation of the results of the impact test proves conclusively that material should not be judged by testing one specimen. A number of tests should be made and the average obtained. The impact strength of the original test varied from 26.2 to 64.1 feet pounds per square inch, the average being 48.1. (See table.) The other specimens varied in the same manner.

CHARPY IMPACT TESTS ON STEEL AXLES AND CRANK PINS.

At the request of a steel company, Charpy impact tests were made on a number of notched bars taken from locomotive axles and crank pins. The physical and chemical data, other than the hardness and impact tests and micrographs, were furnished by the steel works.

An examination of the results obtained indicates that the large number of variables renders a definite conclusion difficult. For instance, some of the pieces are of carbon steel and some of nickel chrome. The carbon contents vary as do the heat treatments. The heat treatments furnished do not agree with the micrographs. For instance, in specimen No. 3 the needle structure has not been wiped out as would be expected with the heat treatment given. The metal in specimen D shows no evidence of heat treatment. It seems most logical, therefore, to compare the micrographs and the impact tests, as both of these were made at this arsenal and represent the present condition of the metal.

An examination of the micrographs shows that the worst structures are those for specimen 4, D, 3, T, and in the order stated. Four Charpy transverse specimens were tested in each case, and the results show D and T to have the least resistance to shock, while 4 gives very low results. No. 3, however, is rather tough. The micrographs indicate that H. D. 1, 2, 7, and 5 have the best structure, in the order given. The impact tests are 7, 5, 6, 3, 2, H. D. 1, and H. D. 2, in order. The results obtained with the impact tensile specimens are so erratic that no comparisons have been made. The results indicate that the steel with the best structure will give the highest test under impact, while coarse, uneven structures are very weak and brittle.

It is thought that better results would be obtained if the number of variables were reduced. The summary gives the results in the order of their importance.

Summary showing results in the order of their importance.

Elastic limit.	Tensile strength.	Elongation.	Contraction.	Charpy tests.		Ball test.	C.	Ni.	Cr.
				Transverse.	Tensile.				
HD1	HD1	I	1	7	HD2	8	1	5	5
HD2	HD2	T	HD1	5	7	2	HD1	8-2	2
8	2-8	D	HD2	6-3	5	7	4	2-8	8
3	8-2	3	3	3-6	HD1	HD2	2-8	7	7
5-2	6	HD1	T	2	T-3	HD1	8-2	7	7
2-5	7	5	D	HD1	3-T	6	5	....	....
6	5	2	2	HD2	4	5	6-T	....	....
7	3	HD2	8	8	D	1	T-6	....	....
1	1-4	8	5	4	8	4	HD2	....	....
4	4-1	4	4	1	1	3	7	....	....
D	T	6	6	D-T	2	T	3	....	....
T	D	7	7	T-D	(?)	D	D	....	....

Specimen No.
1
2
3
4
5
6
7

Specimen No.
8
D
T
HD-1
HD-2

COMPARISON OF TANGENTIAL VERSUS LONGITUDINAL SPECIMENS.

A COMPARISON OF TANGENTIAL VERSUS LONGITUDINAL SPECIMENS.

Although it is generally admitted that tangential specimens taken from forged steel are weaker than longitudinal specimens, very little data can be found as to how these two compare.

Frequently we find that test specimens are taken out longitudinally, although the service stress is applied tangentially. This sometimes leads to unexpected failures which would not occur if the specimens for acceptance test were taken in the direction in which the service stress is applied.

For the purpose of obtaining data on this question, the following experiments were made. The first experiment was made on a piece of drawn tubing. This was selected because the drawing operation tended to extend the metal in two directions, viz, longitudinally and tangentially. It was expected that the difference in the two specimens would be less in this case than in experiment No. 2, where the metal was drawn out in one direction only.

EXPERIMENT No. 1.

A piece of 6-inch drawn-steel tubing, purchased for the manufacture of howitzer spring cylinders, was cut open, heated, and flattened in the smith shop. Longitudinal and transverse specimens were then cut out to the dimensions shown in sketch No. 1. After annealing for two hours at 800° C. the pieces were tested, with the following results:

Marks.	Dimensions.		Sectional area.	Elastic limit.		Tensile strength.	
	Width.	Thickness.		Total. pounds.	Pounds per square inch.	Total, pounds.	Pounds per square inch.
	Inch.	*Inch.*	*Sq. inch.*				
T-2.......	0.500	0.256	0.128	4,700	36,700	8,100	63,300
T-3.......	.502	.251	.126	4,500	35,700	7,854	63,000
T-4.......	.497	.232	.115	3,672	31,900	6,324	55,000
T-5.......	.500	.228	.114	3,672	32,200	6,324	55,500
T-6.......	.500	.228	.114	3,570	31,300	6,222	54,500
L-1.......	.501	.240	.120	3,978	33,100	7,140	59,500
L-3.......	.502	.249	.125	4,386	35,100	7,446	59,600
L-4.......	.505	.260	.131	4,692	35,800	8,364	63,900
L-5.......	.503	.259	.130	4,590	35,300	8,058	62,000
L-6.......	.501	.251	.126	4,590	36,400	8,058	64,000

Marks.	Elongation in 2 inches.		Elongation in inch sections.		Dimensions at fracture.	Contraction of area.	Appearance of fracture.
	Inch.	*Per cent.*	*Inch.*		*Inch.*	*Per cent.*	
T-2......	0.45	22.5	0.12	*0.33	0.39 by 0.20	39.1	Lamellar.
T-3......	.44	22.0	*.29	.15	.39 by .19	41.3	Silky.
T-4......	.47	23.5	.12	*.35	.36 by .16	49.5	Do.
T-5......	.53	26.5	.12	*.41	.35 by .17	48.2	Do.
T-6......	.45	22.5	.10	*.35	.35 by .15	54.4	Do.
L-1......	.55	27.5	.15	*.40	.36 by .17	49.2	Do.
L-3......	.71	35.5	.30	*.41	.37 by .17	49.6	Do.
L-4......	.59	29.5	.20	*.39	.37 by .19	46.5	Do.
L-5......	.59	29.5	.21	*.38	.37 by .17	51.5	Do.
L-6......	.55	27.5	.25	*.30	.37 by .19	44.5	Do.

*Inch section in which fracture occurred.

Summary.

	Elastic limit (pounds per square inch.)	Tensile strength (pounds per square inch.)	Elongation.	Contraction.
Tangential:			*Per cent.*	*Per cent.*
Average	33,560	58,260	23.4	46.5
Maximum	36,700	63,000	26.5	54.4
Minimum	31,300	54,500	22.0	39.1
Difference	5,400	8,500	4.5	15.3
Longitudinal:				
Average	35,140	61,840	29.9	48.3
Maximum	36,400	64,000	35.5	51.5
Minimum	33,100	59,500	27.5	44.5
Difference	3,300	4,500	8.0	7.0

An examination of the summary shows that in every one of the physical properties the average of the longitudinal pieces is better than the corresponding average for the tangential pieces, but this difference is not as great as in experiment No. 2, where the metal was forged in one direction only.

From the column of differences between maximum and minimum it is seen that the longitudinal pieces are much more uniform than the tangential in elastic limit, tensile strength, and contraction of area.

EXPERIMENT NO. 2.

The specimens tested in this experiment were taken from the bases and walls of four 6-inch shrapnel cases marked A, B, C, and D. All four cases were made from forged or rolled bar stock. Cases A and D showed a number of slag streaks, while B and C were apparently free from seams or streaks. Cases A and B were heat treated in the bar, while C and D were heat treated after rough machining. Specimens marked L were taken out longitudinally, those marked T were taken tangentially, as shown in sketch No. 2.

Specimen number.	Elastic limit.	Tensile strength.	Elongation in 2 inches.	Contraction.	Remarks.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent.*	*Per cent.*	
AL	116,000	144,000	15.5	40.3	
AL	121,500	150,500	14.5	37.2	
AT	111,500	136,500	5.5	9.5	
AT	108,000	137,000	7.5	13.3	
BL	111,000	142,000	11.5	34.0	
BL	106,500	138,500	17.0	46.2	
BT	87,500	123,000	5.5	5.7	
BT	87,500	121,500	5.0	9.5	
CL	100,500	133,000	18.0	57.2	
CL	97,000	130,500	18.0	57.2	
CT	92,000	124,500	13.0	27.4	
CT	95,500	127,000	12.5	27.4	
DL	100,500	137,500	17.5	57.2	
DL	98,500	139,500	14.5	59.8	
DT	92,500	104,500	2.0	1.8	Brown streak near circumference.
DT	([1])	49,500	0	0	Broke at flaw.

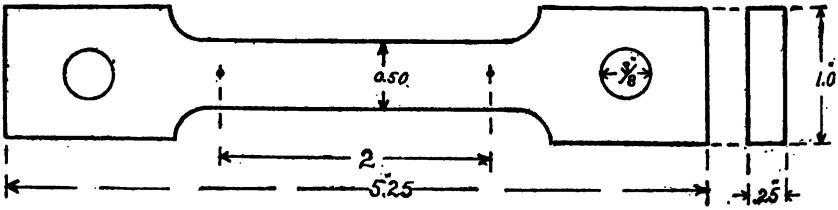
[1] Not obtained.

Summary.

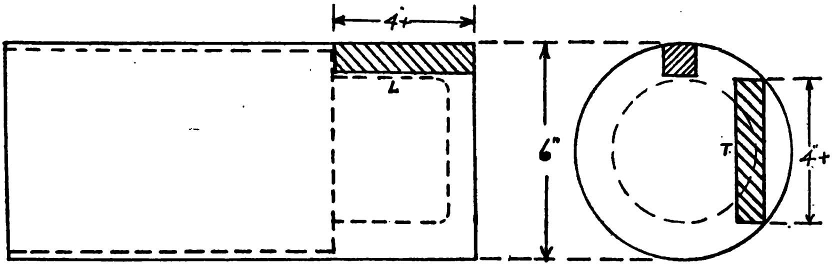
	Elastic limit (pounds).				Tensile strength.			
	A	B	C	D	A	B	C	D
Longitudinal	118,750	108,750	98,750	99,500	147,250	140,500	131,750	138,500
Tangential	109,750	87,500	93,750	92,500	136,750	122,250	125,700	104,500
Difference	9,000	21,000	5,000	7,000	10,500	18,250	6,050	34,000
Per cent difference from longitudinal	7.6	19.3	5.1	7.0	7.1	13.0	4.6	24.6

	Elongation (per cent).				Contraction (per cent).			
	A	B	C	D	A	B	C	D
Longitudinal	15.0	14.3	18.0	16.0	38.8	40.1	57.2	58.5
Tangential	6.3	5.3	12.8	2.0	11.4	7.6	27.4	1.8
Difference	8.7	9.0	5.2	14.0	27.4	32.5	29.8	56.7
Per cent difference from longitudinal	58.0	63.0	28.8	87.5	70.6	81.0	52.0	97.0

In every case the average of the longitudinal specimens is better than for the tangential. The greatest difference appears in the ductility.



SKETCH NO. 1.



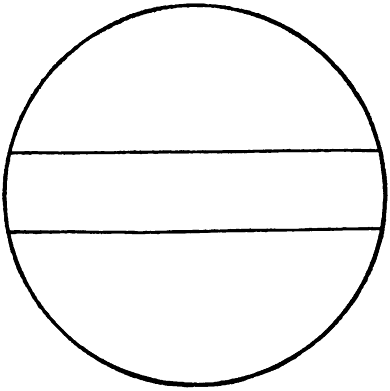
SKETCH NO. 2.

EXPERIMENT NO. 3.

The specimens for this experiment were taken from three bars which had been forged from a 10-inch billet to bars 5 inches diameter. The chemical composition was as follows:

	Per cent.
C	0.50
Si	.27
Mn	.69
S	.026
P	.024
Ni	3.50

The bars were quenched in oil at 800° C. and drawn two hours at 400° C. After heat treatment test pieces were taken parallel and normal to the direction of forging. It was impossible to cut tangential specimens from such a small bar; therefore they were taken across a diameter as shown in sketch below.



It is believed that tangential and radial specimens would give the same physical properties in a bar of this kind, as both are taken normal to the direction of forging.

Specimens taken along the bar are marked L, and those taken across a diameter are marked T.

Specimen number.	Elastic limit.	Tensile strength.	Elongation in 2 inches.	Contraction.	Remarks.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent.*	*Per cent.*	
1 L	119,500	154,000	10.5	46.2	
1 L	121,000	154,000	12.5	46.2	
1 T	106,500	145,000	8.0	20.5	
1 T	Not obtained.	71,000	2.0	5.7	Broke at flaw.
2 L	120,500	164,000	11.5	46.2	
2 L	119,500	152,500	12.5	46.2	
2 T	109,000	147,000	10.0	20.5	
2 T	105,000	143,000	9.0	16.9	
3 L	124,500	153,500	11.5	46.2	
3 L	127 500	161,500	11.0	46.2	
3 T	88,000	142,500	7.5	13.3	
3 T	87,000	141,500	7.5	13.3	

Summary.

Specimen.	Elastic limit.	Tensile strength.	Elongation.	Contraction.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Per cent.*	*Per cent.*
Longitudinal	122,100	156,600	16.6	46.2
Tangential	99,100	131,700	7.3	15.0
Difference	23,000	24,900	9.3	31.2
Per cent difference from longitudinal	18.8	15.9	56.0	67.5

As before, it was found that the longitudinal pieces were better in all respects than the tangential. The principal difference appears in the ductility. The contraction of area is constant at 46.2 per cent for all longitudinal specimens, whereas the tangential tests vary from 5.7 to 20.5 per cent.

CONCLUSIONS.

1. Specimens taken normal to the direction of forging are lower in all physical properties than those taken along the direction of forging. The ductility is more sensitive in this respect than the elastic limit and tensile strength.

2. Longitudinal specimens are much more uniform than those taken normal to the direction of forging.

EXPERIMENTS ON HEAT TREATMENT OF STEEL.

HEAT TREATMENT OF NICKEL VANADIUM STEEL.

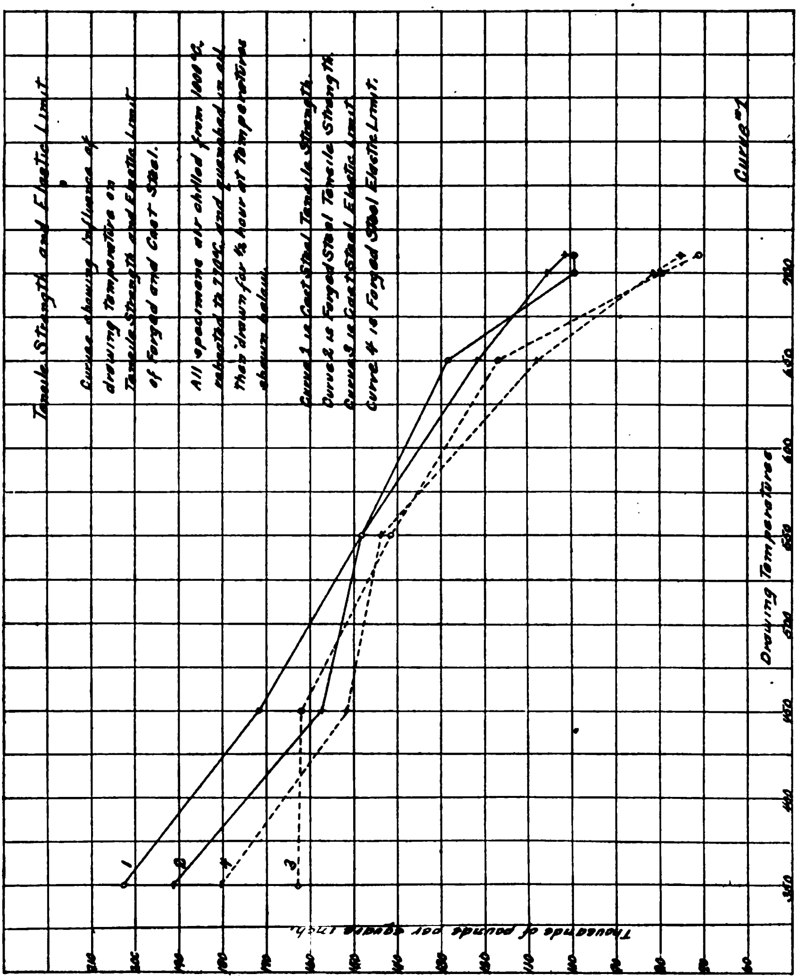
EXPERIMENT NO. 3150.

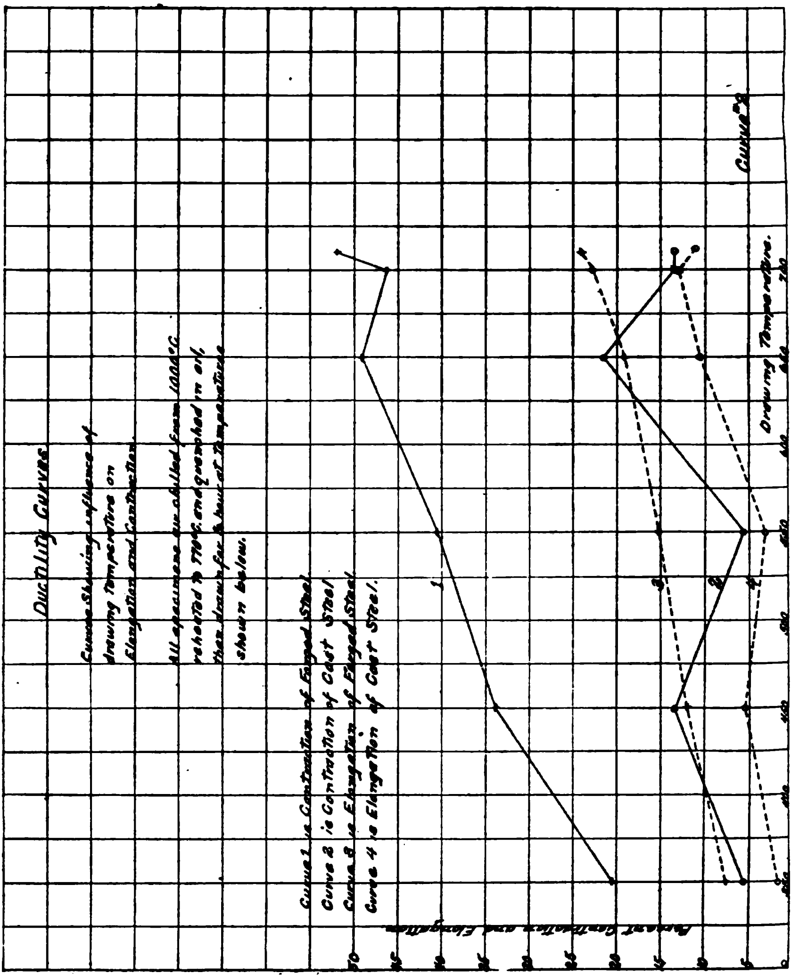
The following experiment was made from ingot No. 3150, which was cast in steel heat No. 4066. The heat analyzed as follows:

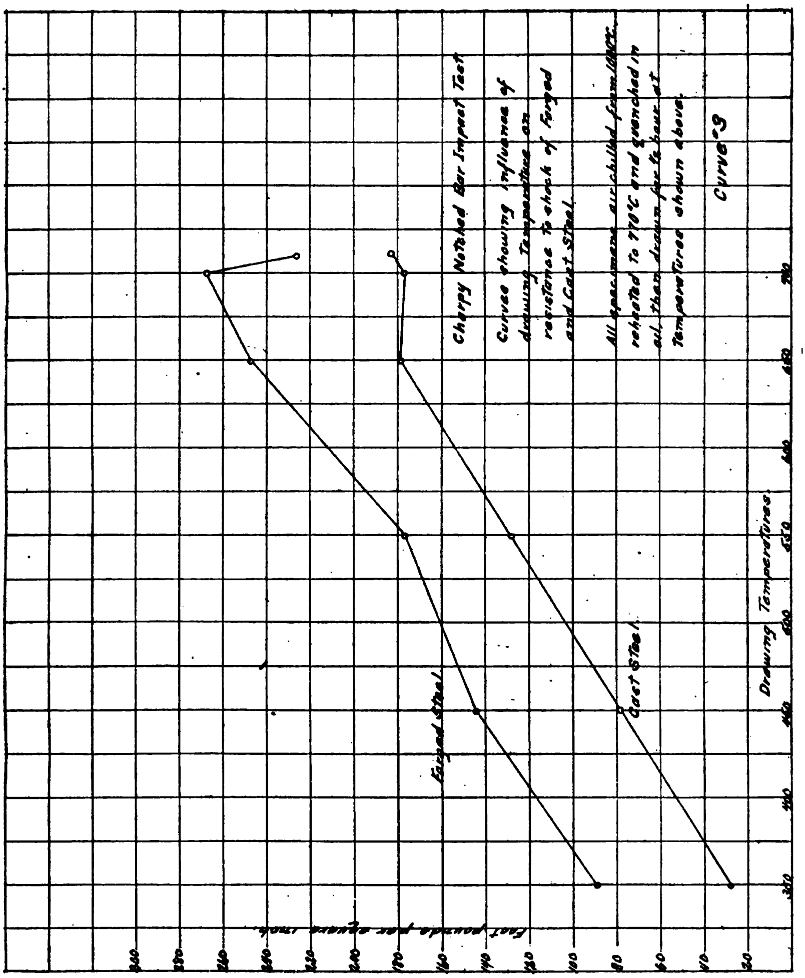
	Per cent.
C	0.455
Mn	.50
Si	.23
S	.049
P	.033
Ni	3.45
Va	.27

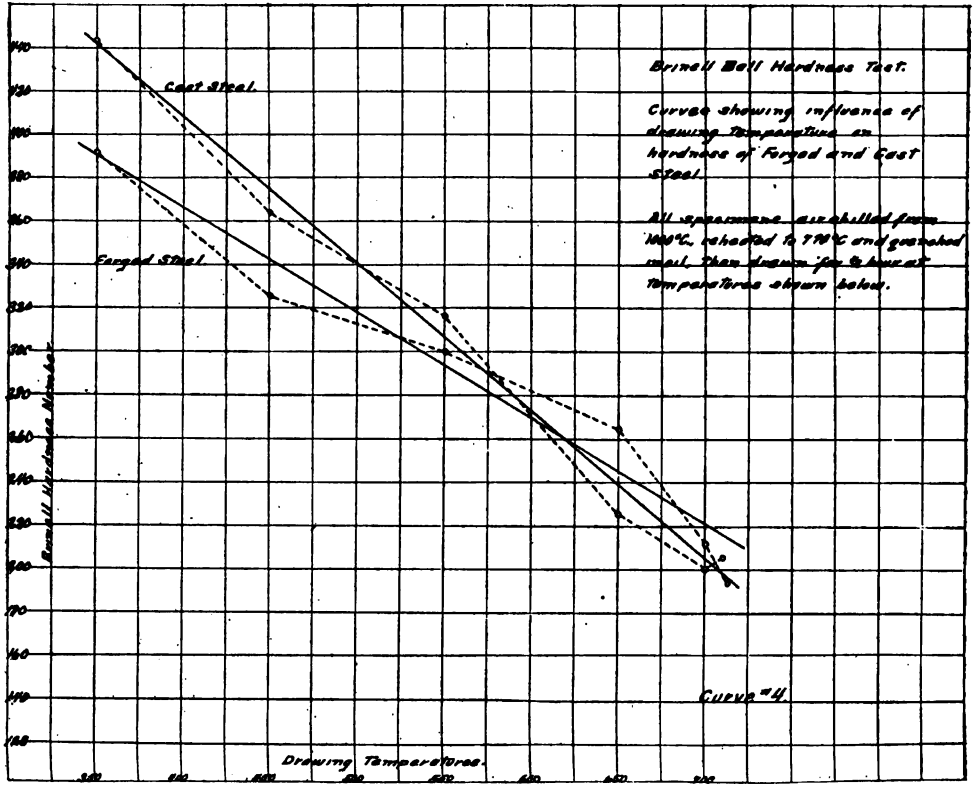
The ingot was cast in a dry-sand mold, was 20 inches diameter and approximately 50 inches long. After casting, the ingot was heated to 950° C., air chilled, then returned to furnace at about 400° C. and allowed to cool with furnace. It was then sent to the machine shop, where discards were taken from the top and the bottom. The discard from the bottom of the ingot was 4 inches thick by 20 inches diameter. All test specimens in experiment No. 3150 were made from this bottom discard as described below. This disk was then split into two semicircular pieces, one-half being forged down to a slab 5 inches wide by 1 inch thick, the other remaining in the cast condition. The forging operations were all normal and the forging was finished at a dull red heat, and above the critical temperature. Specimens approximately 1 by 1 by 5 inches were machined out from the cast and forged, stock suitably marked, and heat treated as shown below. All specimens were first heated to 1,000° C. and air chilled for the removal of ingotism. They were then oil quenched from 770° C. Both forged and cast steels were given exactly the same heat treatment for the same length of time in order that a direct comparison could be made.

The accompanying curves show in a graphic manner the results which were obtained. Curve No. 4 shows the Brinell ball hardness number for both steels. It will be noted that the cast steel is harder than the forged steel. From this we would expect a higher elastic limit and tensile strength for the cast stèel, and this is shown in curve No. 1. Hard steel is usually brittle steel, and curve No. 3 shows that for the cast metal the impact strength was lower than for the forged. From the tables we see that for the same heat treatment practically the same elastic limit and tensile strength are obtained for the cast metal as for the forged, but we also see that the ductility is greatly increased by forging. Forging appears to also increase the impact strength.


Tensile Strength and Elastic Limit
Curves showing influence of
drawing temperature on
Tensile Strength and Elastic Limit
of Forged and Cast Steel.
All specimens air chilled from 1000 C.
reheated to 770 C. and quenched in oil
Then drawn for ½ hour at temperatures
shown below.
Curve 1 is Cast Steel Tensile Strength.
Curve 2 is Forged Steel Tensile Strength.
Curve 3 is Cast Steel Elastic Limit.
Curve 4 is Forged Steel Elastic Limit.
Curve No 1
1
2
3
4
Thousands of pounds per square inch.
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
Drawing Temperatures
350
400
450
500
550
600
650
700


Ductility Curves
Curves Showing influence of drawing temperature on Elongation and Contraction.
All specimens are chilled from 1000° C reheated to 770° C and quenched in oil then drawn for ½ hour at temperature shown below.
Curve 1 is Contraction of Forged Steel
Curve 2 is Contraction of Cast Steel
Curve 3 is Elongation of Forged Steel
Curve 4 is Elongation of Cast Steel.
Curve No 3
Percent Contraction and Elongation
50
45
40
35
30
25
20
15
10
5
0
Drawing Temperature.
350
400
450
500
550
600
650
700
1
2
3
4


Charpy Notched Bar Impact Test
Curves showing influence of drawing Temperature on resistance to shock of Forged and Cast Steel.
All specimens air chilled from 1000°C. reheated to 770°C and quenched in oil, then drawn for ½ hour at Temperatures shown above.
Curve 3
Forged Steel.
Cast Steel.
Drawing Temperatures.
350
400
450
500
550
600
650
700
Foot pounds per square inch.
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20


Brinell Ball Hardness Test.
Curves showing influence of drawing temperature on hardness of Forged and Cast Steel.
All specimens air chilled from 1000°C., reheated to 770°C and quenched in oil, then drawn for ½ hour at temperatures shown below.
Cast Steel.
Forged Steel.
Curve #4.
Brinell Hardness Number
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
Drawing Temperatures.
350
400
450
500
550
600
650
700

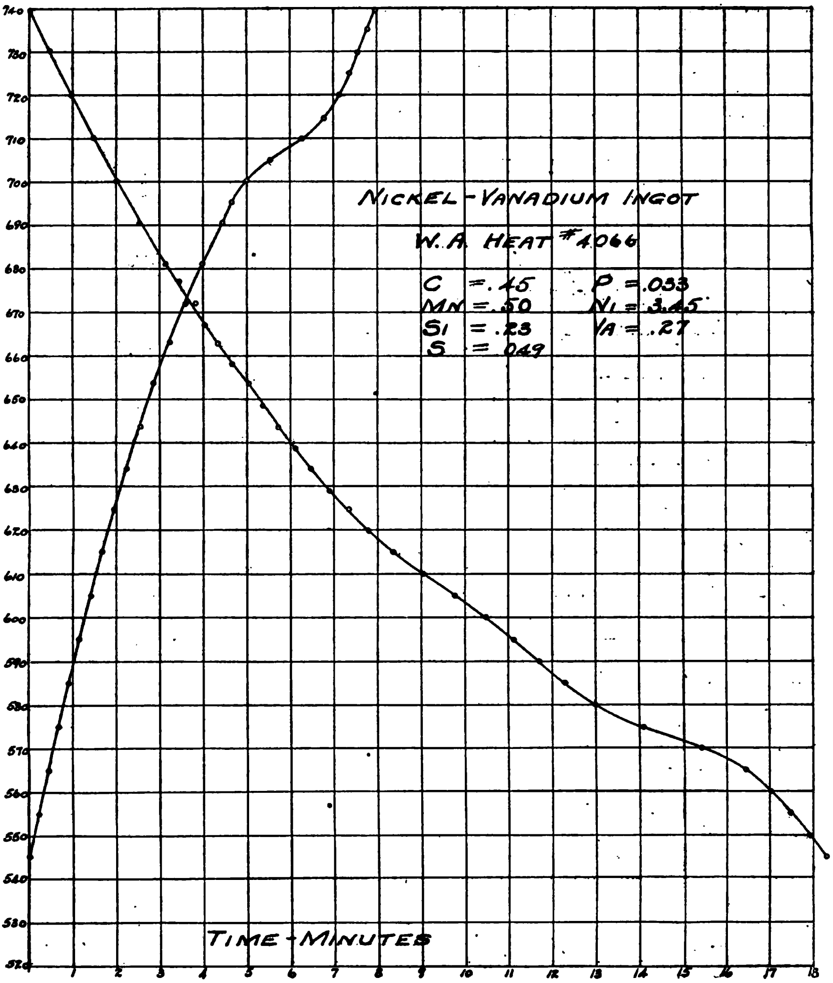
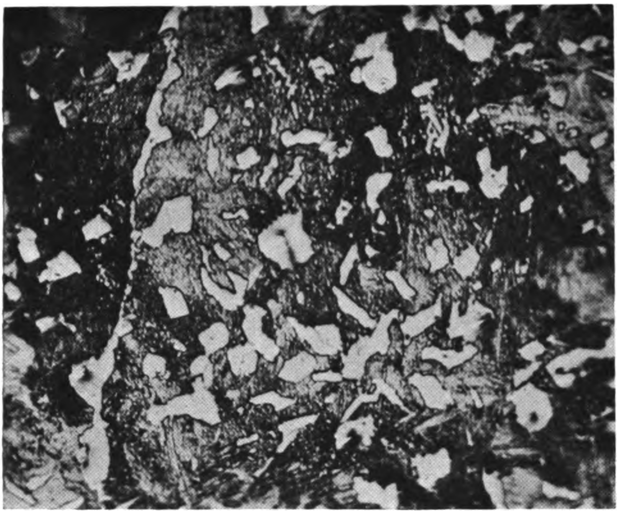

NICKEL-VANADIUM INGOT
W.A. HEAT #4066
C = .45
MN = .50
SI = .23
S = .049
P = .033
NI = 3.45
VA = .27
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540
530
520
TIME-MINUTES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

TABLE No. 1.

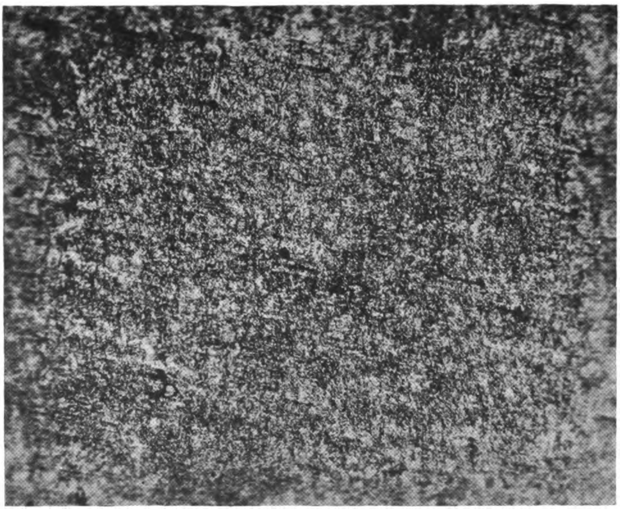
Specimen number.	Heat treatment.	Elastic limit (lbs. per sq. in.).	Tensile strength (lbs. per sq. in.).	Elongation.	Contraction.	Charpy impact test (ft. lbs. per sq. in.).	Brinell ball hardness number.
				P. ct.	P. ct.		
3150AX	As cast	73,500	93,000	2.0	5.7	Maximum, 24.3 Minimum, 11.4 Average,[1] 15.5	Maximum, 248 Minimum, 228 Average, 242
3150A6 [2]	Oil quenched from 770° C.; drawn one-half hour at 710° C.	71,000	99,500	11.0	13.3	Maximum, 186.0 Minimum, 178.7 Average,[1] 182.3	Maximum, 207 Minimum, 202 Average, 205
3150A1 [2]	Oil quenched from 770° C.; drawn one-half hour at 700° C.	79,500	99,500	13.0	13.3	Maximum, 194.0 Minimum, 163.5 Average,[1] 176.0	Maximum, 212 Minimum, 196 Average, 200
3150A2 [2]	Oil quenched from 770° C.; drawn one-half hour at 650° C.	117,000	128,500	10.5	24.0	Maximum, 178.7 Minimum, 178.2 Average,[1] 178.5	Maximum, 228 Minimum, 223 Average, 225
3150A3 [2]	Oil quenched from 770° C.; drawn one-half hour at 550° C.	141,500	148,000	3.0	5.7	Maximum, 189.7 Minimum, 64.6 Average,[1] 127.4	Maximum, 321 Minimum, 311 Average, 316
3150A4 [2]	Oil quenched from 770° C.; drawn one-half hour at 450° C.	162,000	171,500	5.5	13.3	Maximum, 117.5 Minimum, 64.6 Average,[1] 77.8	Maximum, 364 Minimum, 364 Average, 364
3150A5 [2]	Oil quenched from 770° C.; drawn one-half hour at 350° C.	163,000	202,500	1.5	5.7	Maximum, 39.1 Minimum, 23.0 Average,[1] 28.3	Maximum, 444 Minimum, 444 Average, 444

[1] Six specimens tested.

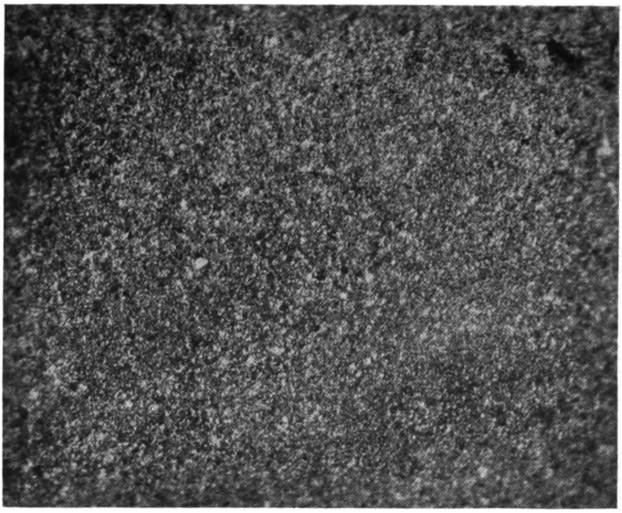
[2] All specimens heated for 1½ hours and air chilled from 1,000° C. before oil quenching as shown.



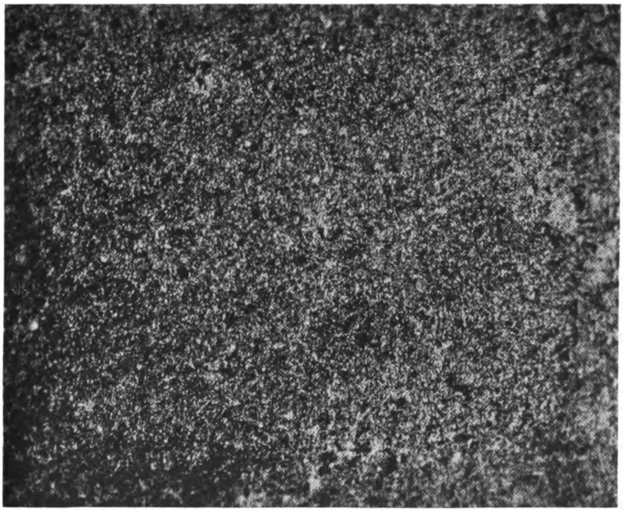
3150 AX. (X75.)



3150 A6. (X75.)

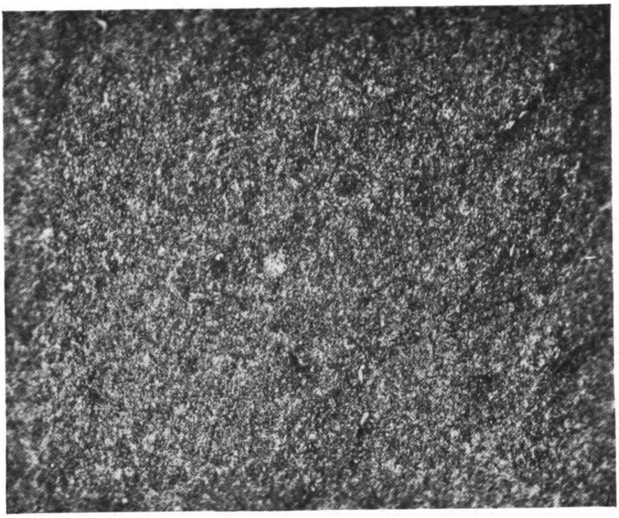


3150 A1. (X75.)

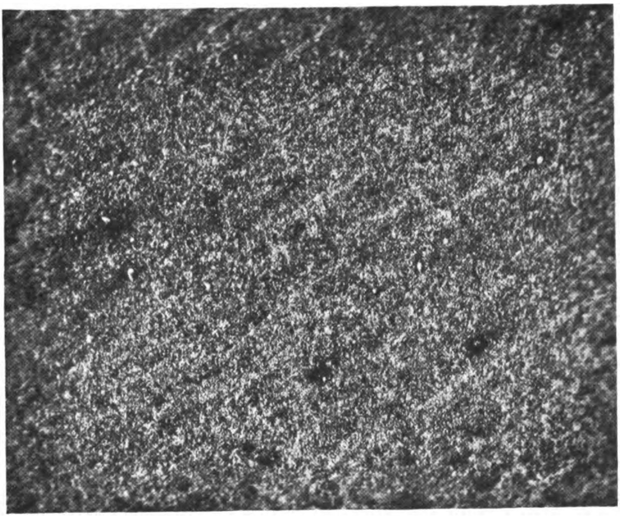


3150 A2. (X75.)

152-2



3150 A3. (X75.)

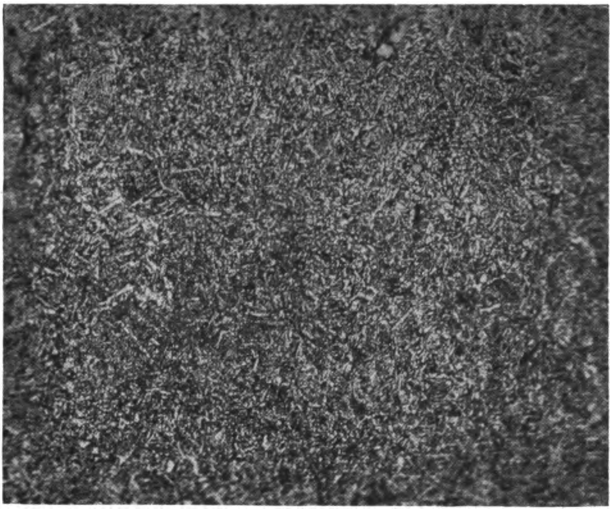


3150 A4. (X75.)

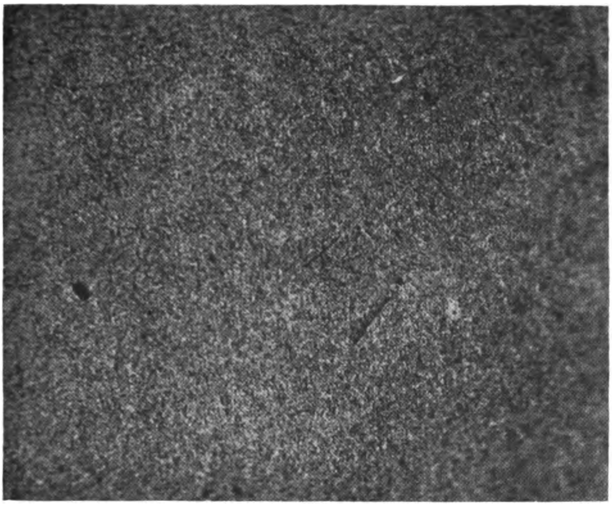
152-3

3150 A5. (X75.)

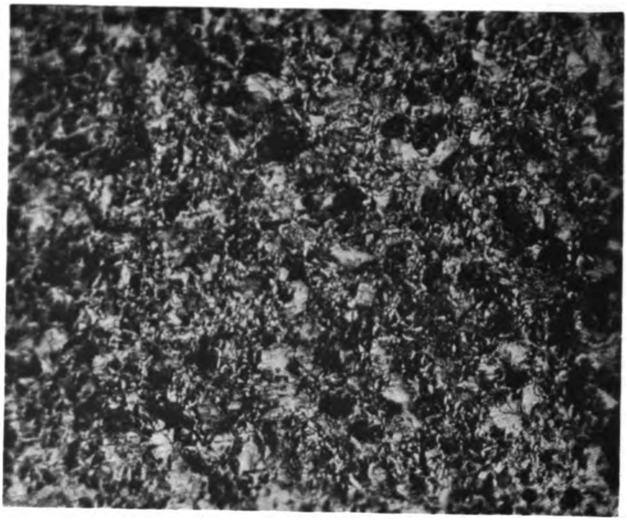
152-4



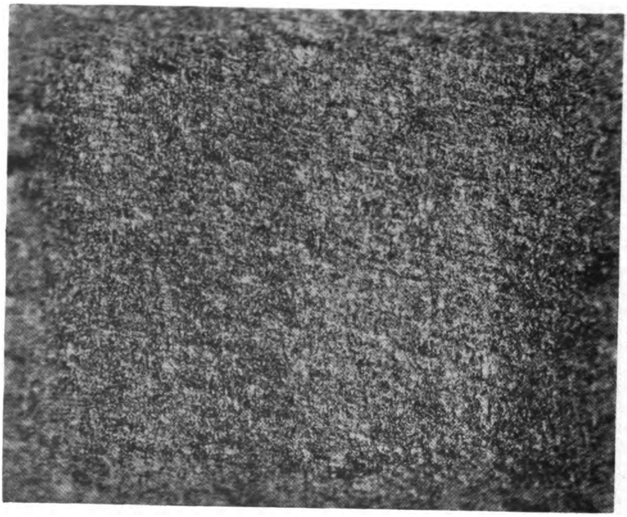
NI.VA. INGOT. AIR CHILLED FROM 1,000° C. UNFORGED. (X75.)



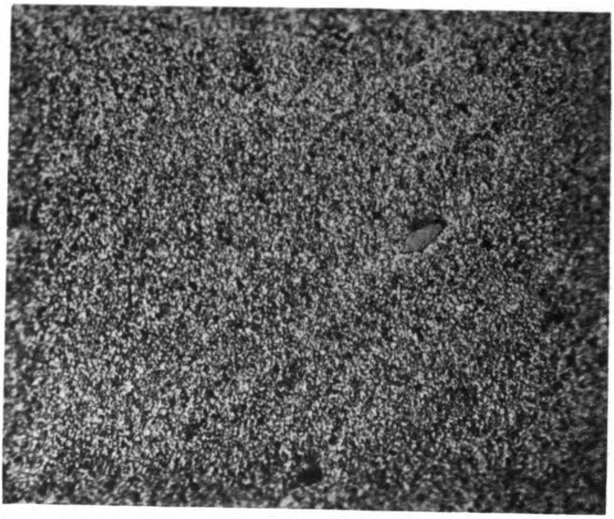
NI.VA. INGOT. AIR CHILLED FROM 1,000° C. OIL QUENCHED FROM 770° C. UNFORGED. (X75.)



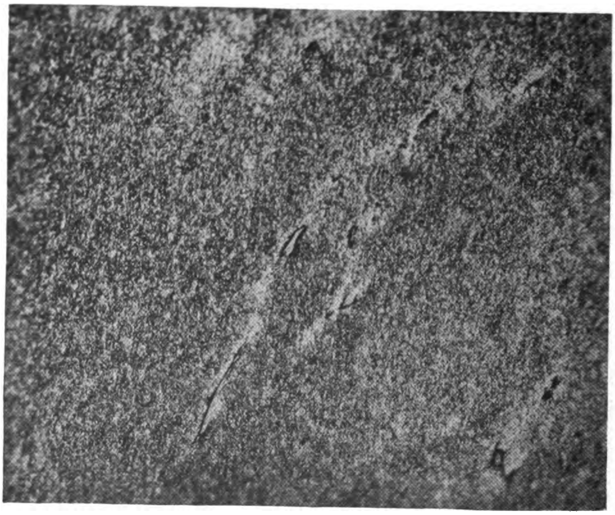
3150 BX. (X75.)



3150 B6. (X75.)

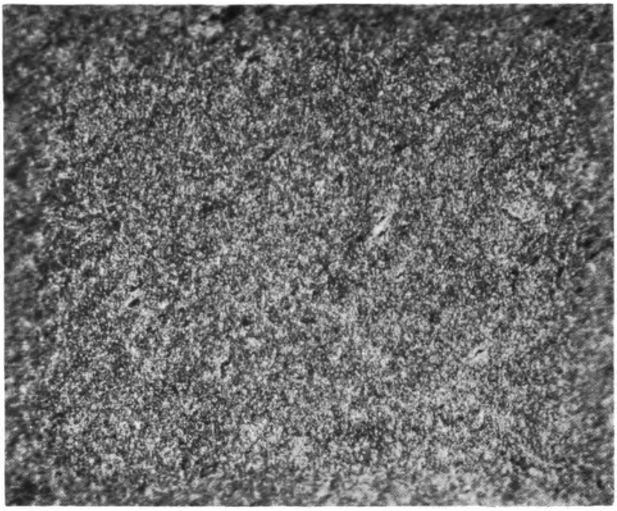


3150 B1. (X75.)



3150 B2. (X75.)

153-2

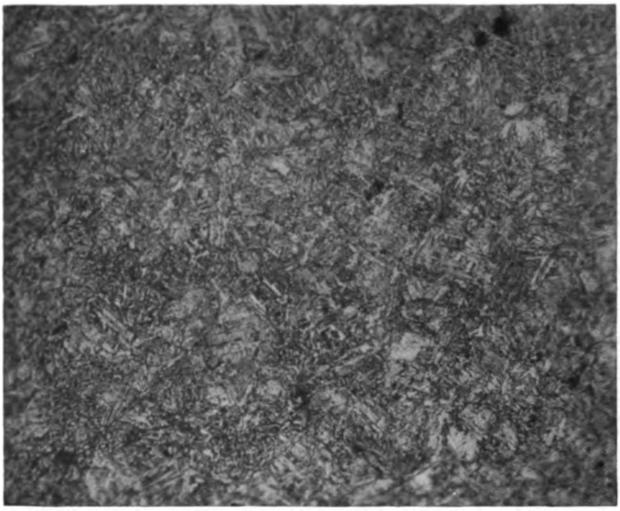


3150 B3. (X75.)

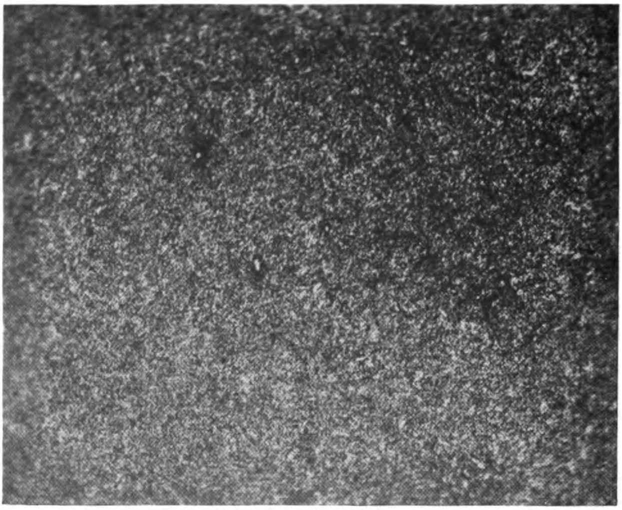
3150 B4. (X75.)

153-3

3150 B5. (X75.)



NI.VA. INGOT. AIR CHILLED FROM 1,000° C. FORGED. (X75.)



NI.VA. INGOT. AIR CHILLED FROM 1,000° C. OIL QUENCHED FROM 770° C. FORGED. (X75.)

TABLE No. 2.

Specimen number.	Heat treatment.	Elastic limit (lbs. per sq. in.).	Tensile strength (lbs. per sq. in.).	Elongation.	Contraction.	Charpy impact test (ft. lbs. per sq. in.).	Brinell ball hardness number.
				P. ct.	*P. ct.*		
3150 BX	As forged.....	96,500	144,000	12.5	20.5	Maximum, 91.6 Minimum, 73.7 Average,[1] 83.8	Maximum, 286 Minimum, 277 Average, 284
3150 B6[2]	Oil quenched from 770° C.; drawn one-half hour at 710° C.	75,000	101,500	24.0	51.9	Maximum, 231.0 Minimum, 214.0 Average,[1] 226.0	Maximum, 196 Minimum, 187 Average, 193
3150 B1[2]	Oil quenched from 770° C.; drawn one-half hour at 700° C.	81,000	105,500	22.5	46.2	Maximum, 320.5 Minimum, 231.4 Average,[1] 266.8	Maximum, 228 Minimum, 196 Average, 211
3150 B2[2]	Oil quenched from 770° C.; drawn one-half hour at 650° C.	107,500	121,500	19.0	49.1	Maximum, 320.5 Minimum, 155.1 Average,[1] 246.8	Maximum, 302 Minimum, 241 Average, 264
3150 B3[2]	Oil quenched from 770° C.; drawn one-half hour at 550° C.	143,500	147,500	15.1	40.3	Maximum, 201.2 Minimum, 150.0 Average,[1] 176.1	Maximum, 321 Minimum, 269 Average, 300
3150 B4[2]	Oil quenched from 770° C.; drawn one-half hour at 450° C.	151,500	157,000	12.0	34.0	Maximum, 166.0 Minimum, 132.0 Average,[1] 144.1	Maximum, 340 Minimum, 321 Average, 326
3150 B5[2]	Oil quenched from 770° C.; drawn one-half hour at 350° C.	180,500	191,500	7.5	20.5	Maximum, 120.5 Minimum, 64.7 Average,[1] 88.6	Maximum, 418 Minimum, 387 Average, 392

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[1] Six specimens tested.

[2] All specimens heated to 1,000° C. for 1½ hours and air chilled before oil quenching as shown.

EXPERIMENTS ON STEEL BY STUDENT OFFICERS.

[Class of 1913-14.]

1. Effect of forging temperatures.
2. Comparison of cast and forged steels.

The following experiments were performed by the student officers on duty at this arsenal.

The object of experiment No. 1 was to show the effect of the finishing temperature of forging on the grain size and physical properties of forged steel.

The object of experiment No. 2 was to show the effect of heat treatment on cast and forged steel.

An ingot of the composition given below was cast in the foundry. A heating and cooling curve of this metal is appended.

For experiment No. 1 a section was forged, finishing at the temperatures shown. Physical tests and micrographs were made after each operation. The results are arranged in a convenient order for comparison.

For experiment No. 2, a section of this ingot was forged, finishing at 1,450° F. Specimens of this forged section and of the original cast metal were given identical heat treatments. Physical tests and micrographs were made after each operation. The results are arranged in a convenient order for comparison.

Chemical analysis of student officer's ingot.

	Per cent.
C	0.332
Mn	.50
Si	.183
S	.051
P	.036

EXPERIMENT NO. 1.

EFFECT OF FORGING TEMPERATURE.

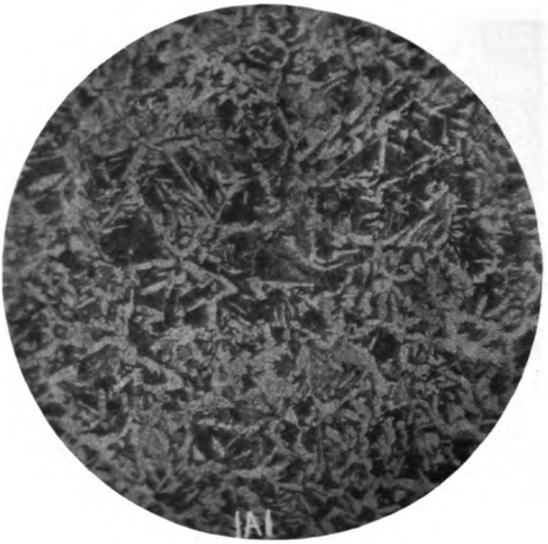


FIG. 1.

Finished at 1,600° F.
Elastic limit, 45,000 pounds per square inch.
Tensile strength, 83,500 pounds per square inch.
Elongation, 25 per cent.
Contraction, 40.3 per cent.

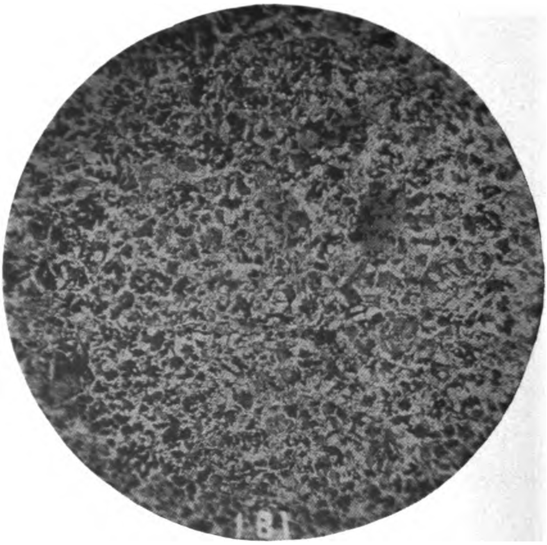


FIG. 2.

Finished at 1,450° F.
Elastic limit, 50,500 pounds per square inch.
Tensile strength, 81,500 pounds per square inch.
Elongation, 23.5 per cent.
Contraction, 27.4 per cent.

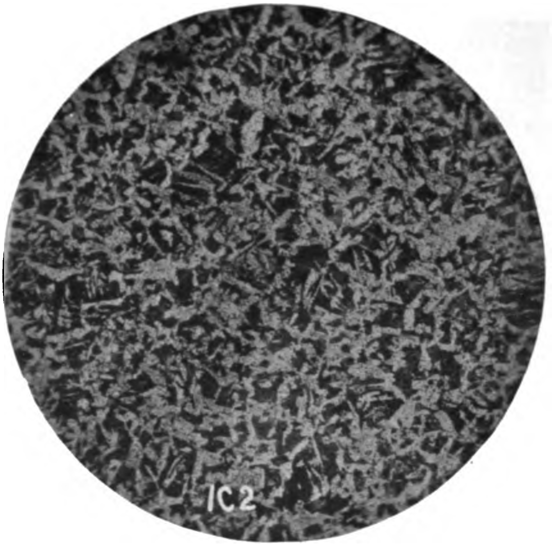


FIG. 3.

Finished at 1,250° F.
Elastic limit, 42,500 pounds per square inch.
Tensile strength, 82,000 pounds per square inch.
Elongation, 25.5 per cent.
Contraction, 37.2 per cent.

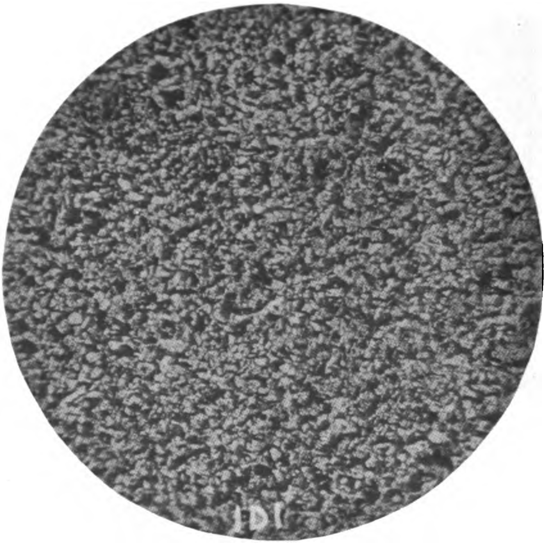


FIG. 4.

Finished at 1,050° F.
Elastic limit, 54,500 pounds per square inch.
Tensile strength, 84,500 pounds per square inch.
Elongation, 22.5 per cent.
Contraction, 34 per cent.

EXPERIMENT NO. 2.

COMPARISON OF CAST AND FORGED STEEL.

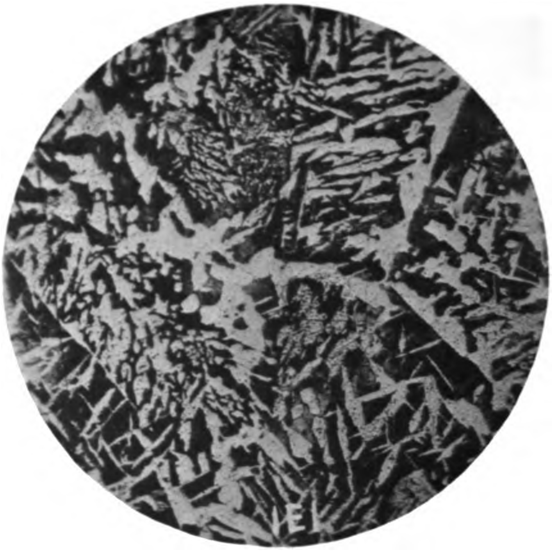


FIG. 5.

Cast steel as cast, unannealed.
Elastic limit, 39,000 pounds per square inch.
Tensile strength, 77,000 pounds per square inch.
Elongation, 10.5 per cent.
Contraction, 16.9 per cent.

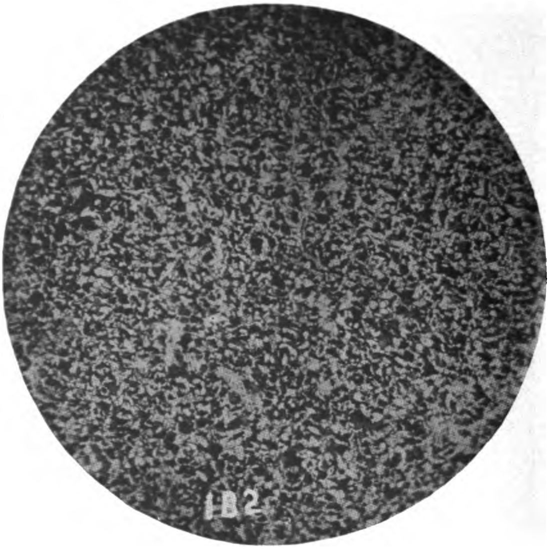


FIG. 6.

Forged steel as forged and not annealed. Forging started at 1,850° F., finished at 1,450° F.
Elastic limit, 50,500 pounds per square inch.
Tensile strength, 83,500 pounds per square inch.
Elongation, 27.5 per cent.
Contraction, 43.3 per cent.
Note.—All forged steel in this experiment forged as above.

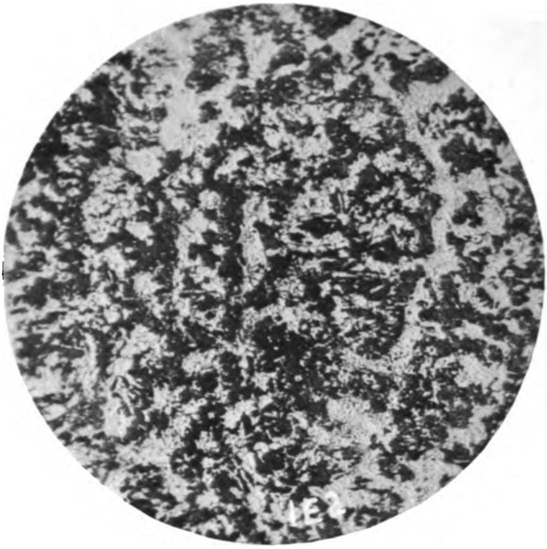


FIG. 7.

Cast steel, annealed at 1,500° F. for three hours and cooled slowly.
Elastic limit, 41,000 pounds per square inch.
Tensile strength, 79,000 pounds per square inch.
Elongation, 19 per cent.
Contraction, 24 per cent.

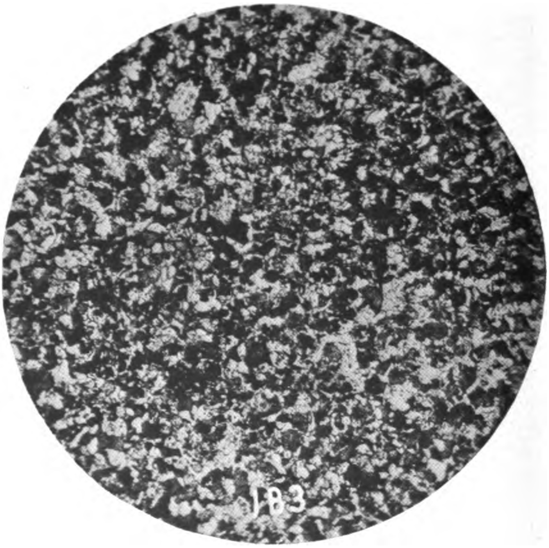


FIG. 8.

Forged steel, annealed same as above.
Elastic limit, 46,000 pounds per square inch.
Tensile strength, 80,500 pounds per square inch.
Elongation, 27 per cent.
Contraction, 46.2 per cent.

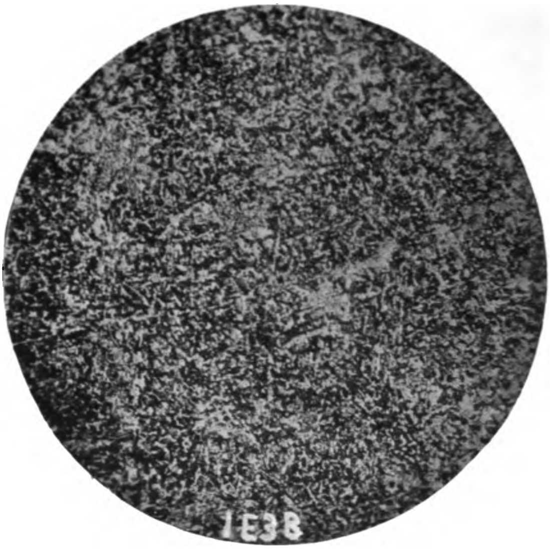


FIG. 9.

Cast steel, cooled in air from 1,500° F.
Elastic limit, 49,500 pounds per square inch.
Tensile strength, 81,000 pounds per square inch.
Elongation, 15.5 per cent.
Contraction, 20.5 per cent.

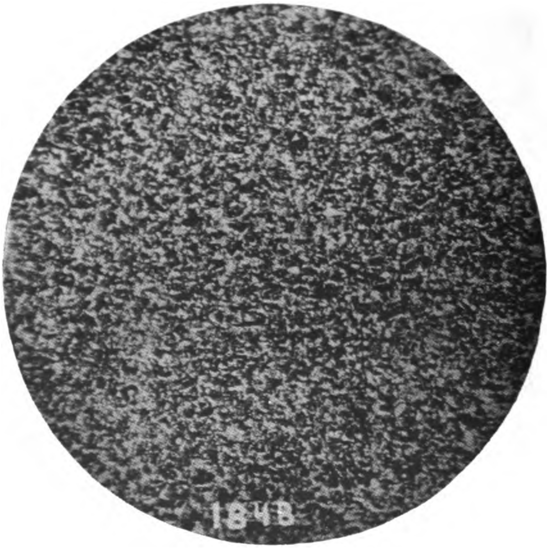


FIG. 10.

Forged steel, heat treatment same as above.
Elastic limit, 54,000 pounds per square inch.
Tensile strength, 84,000 pounds per square inch.
Elongation, 25.5 per cent.
Contraction, 43.3 per cent.

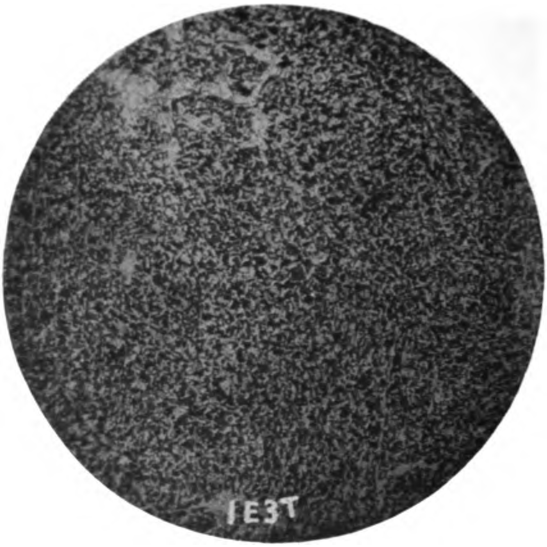


FIG. 11.

Cast steel, chilled in air blast from 1,500° F.
Elastic limit, 50,000 pounds per square inch.
Tensile strength, 79,000 pounds per square inch.
Elongation, 15 per cent.
Contraction, 24 per cent.

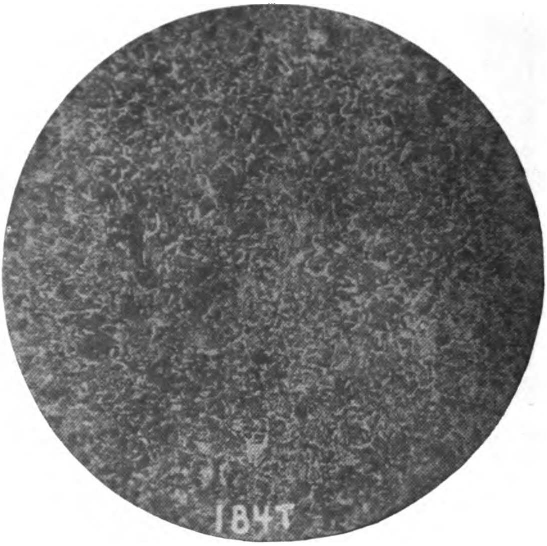


FIG. 12.

Forged steel, heat treatment same as above.
Elastic limit, 55,000 pounds per square inch.
Tensile strength, 85,000 pounds per square inch.
Elongation, 25.5 per cent.
Contraction, 40.3 per cent.

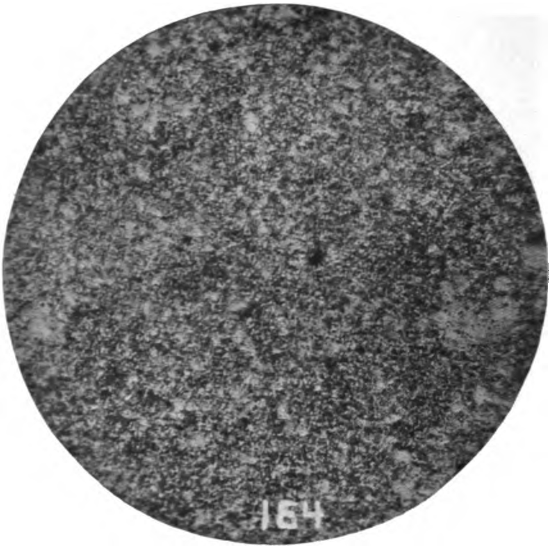


FIG. 13.

Cast steel, quenched in oil from 1,500° F.
Elastic limit, 62,000 pounds per square inch.
Tensile strength, 100,000 pounds per square inch.
Elongation, 11.5 per cent.
Contraction, 24 per cent.

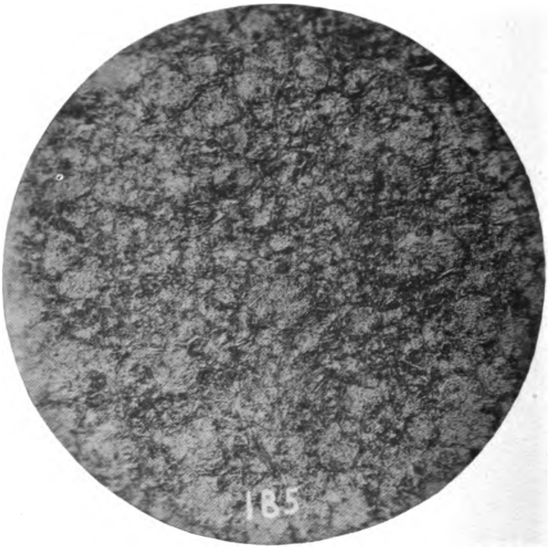


FIG. 14.

Forged steel, heat treatment same as above.
Elastic limit, 68,000 pounds per square inch.
Tensile strength, 109,500 pounds per square inch.
Elongation, 18 per cent.
Contraction, 40.3 per cent.

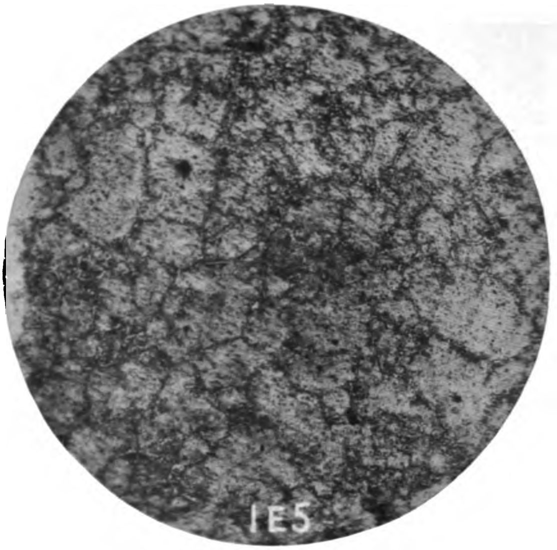


FIG. 15.

Cast steel, quenched in water from 1,500° F., then drawn at 800° F. for two hours.
Elastic limit, 68,000 pounds per square inch.
Tensile strength, 108,500 pounds per square inch.
Elongation, 7 per cent.
Contraction, 9.5 per cent.

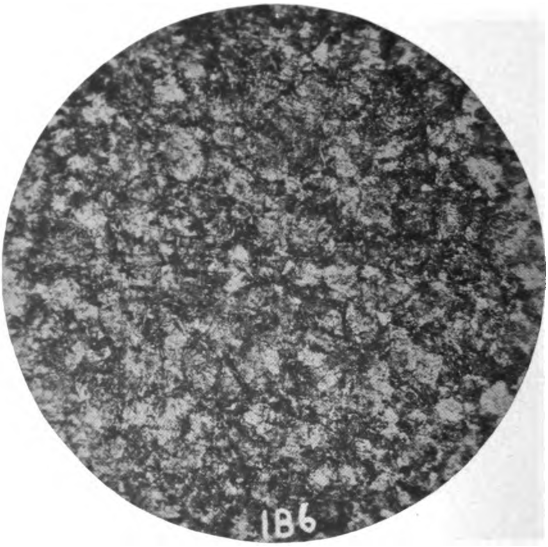


FIG. 16.

Forged steel, heat treatment same as above.
Elastic limit, 65,500 pounds per square inch.
Tensile strength, 117,000 pounds per square inch.
Elongation, 18.5 per cent.
Contraction, 37.2 per cent.

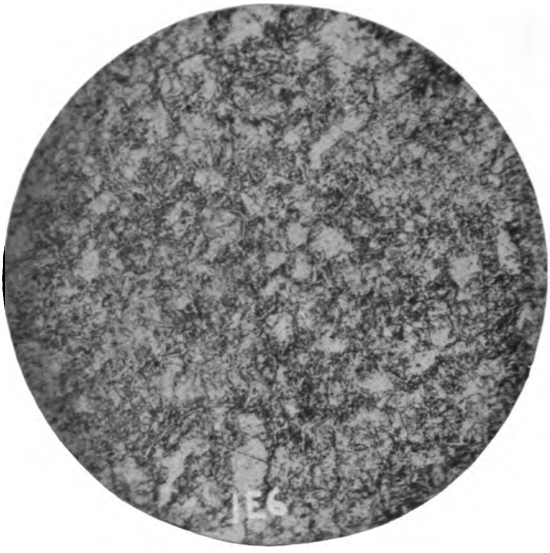


FIG. 17.

Cast steel, quenched in water from 1,500° F., then drawn at 1,000° F. for two hours.
Note.—Temperature ran considerably over 1,000° for a very short time.
Elastic limit, 69,500 pounds per square inch.
Tensile strength, 107,000 pounds per square inch.

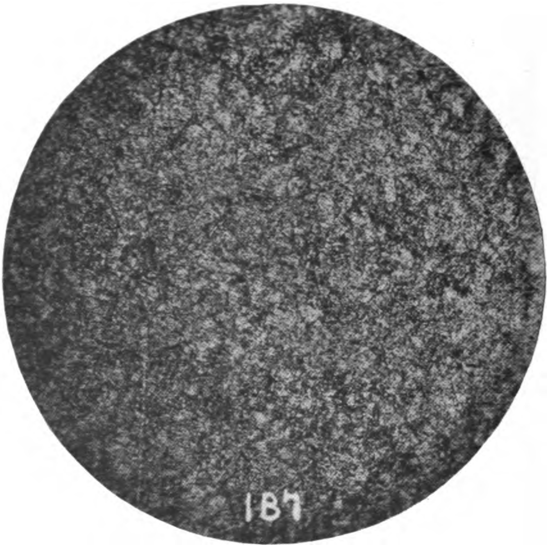


FIG. 18.

Forged steel, heat treatment same as above.
Elastic limit, 66,500 pounds per square inch.
Tensile strength, 101,000 pounds per square inch.
Elongation, 22 per cent.
Contraction, 51.9 per cent.

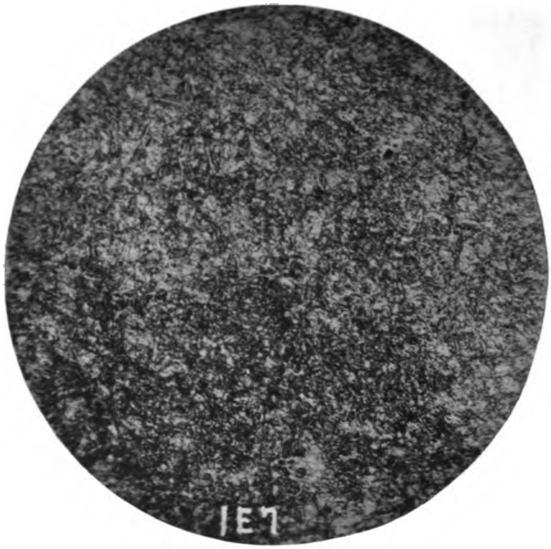


FIG. 19.

Cast steel, quenched in water from 1,500° F., then drawn at 1,200° F. for two hours.
Elastic limit, 58,000 pounds per square inch.
Tensile strength, 91,500 pounds per square inch.
Elongation, 15.5 per cent.
Contraction, 27.4 per cent.

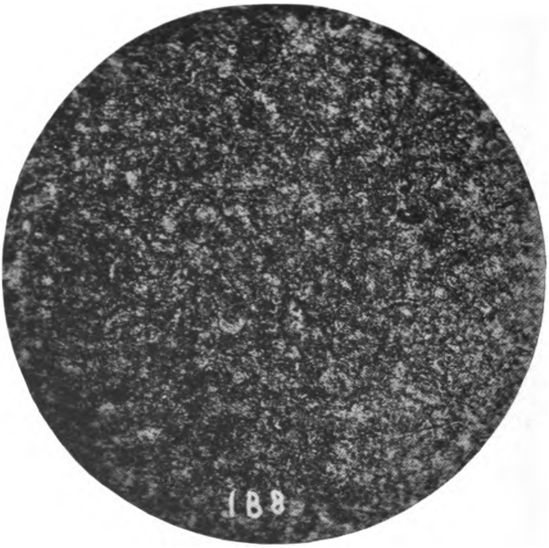


FIG. 20.

Forged steel, heat treatment same as above.
Elastic limit, 55,000 pounds per square inch.
Tensile strength, 88,000 pounds per square inch.
Elongation, 27.5 per cent.
Contraction, 62.3 per cent.

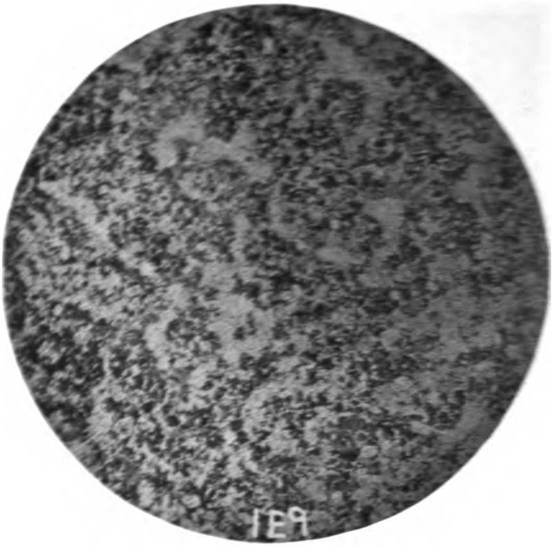


FIG. 23.

Cast steel, quenched in water at 1,500° F., then drawn at 1,500° F. for two hours.
Elastic limit, 48,000 pounds per square inch.
Tensile strength, 78,500 pounds per square inch.
Elongation, 20 per cent.
Contraction, 24 per cent.

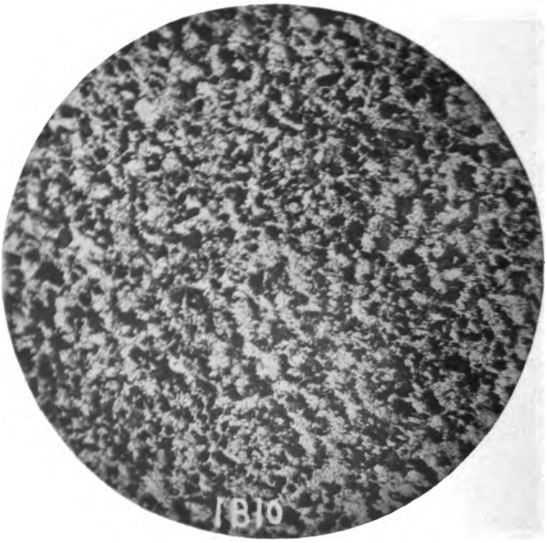
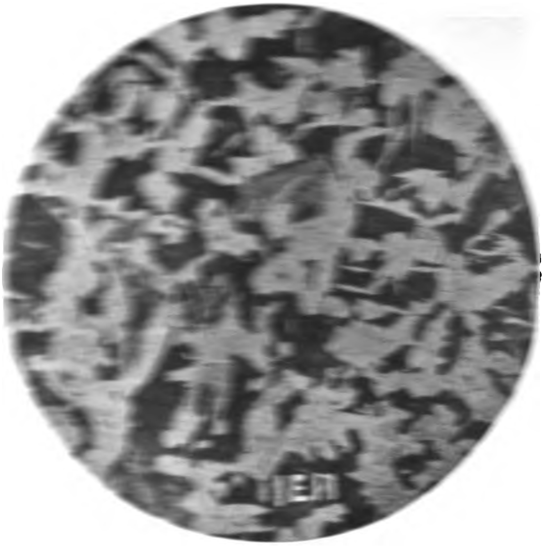


FIG. 24.

Forged steel, heat treatment same as above.
Elastic limit, 47,500 pounds per square inch.
Tensile strength, 80,000 pounds per square inch.
Elongation, 27.5 per cent.
Contraction, 51.9 per cent.



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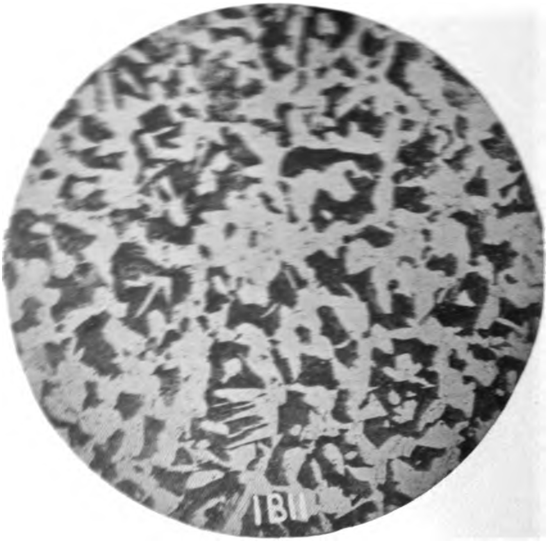


FIG. 26.

Forged steel, heat treatment same as above.
Elastic limit, 40,500 pounds per square inch.
Tensile strength, 79,000 pounds per square inch.
Elongation, 21.5 per cent.
Contraction, 14 per cent.

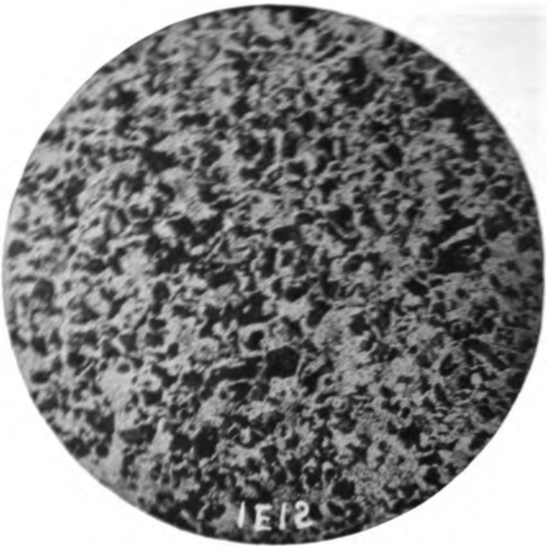


FIG. 27.

Cast steel, quenched in water at 1,500° F. Reheated in crucible to near the melting point of steel. Cooled slowly in lime. Then reannealed at 1,550° F.
Elastic limit, 42,000 pounds per square inch.
Tensile strength, 78,000 pounds per square inch.
Elongation, 16.5 per cent.
Contraction, 27.4 per cent.

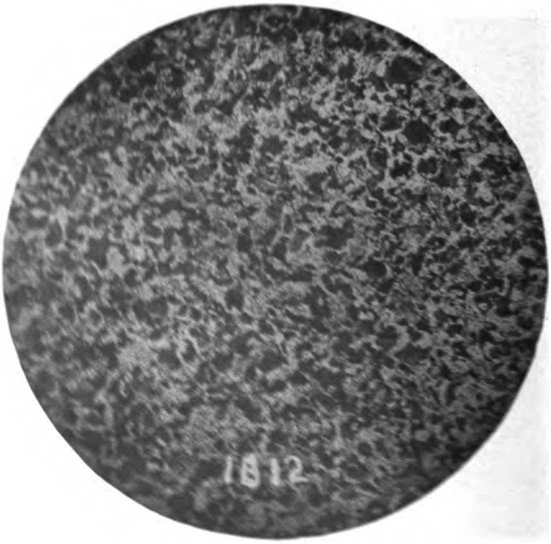
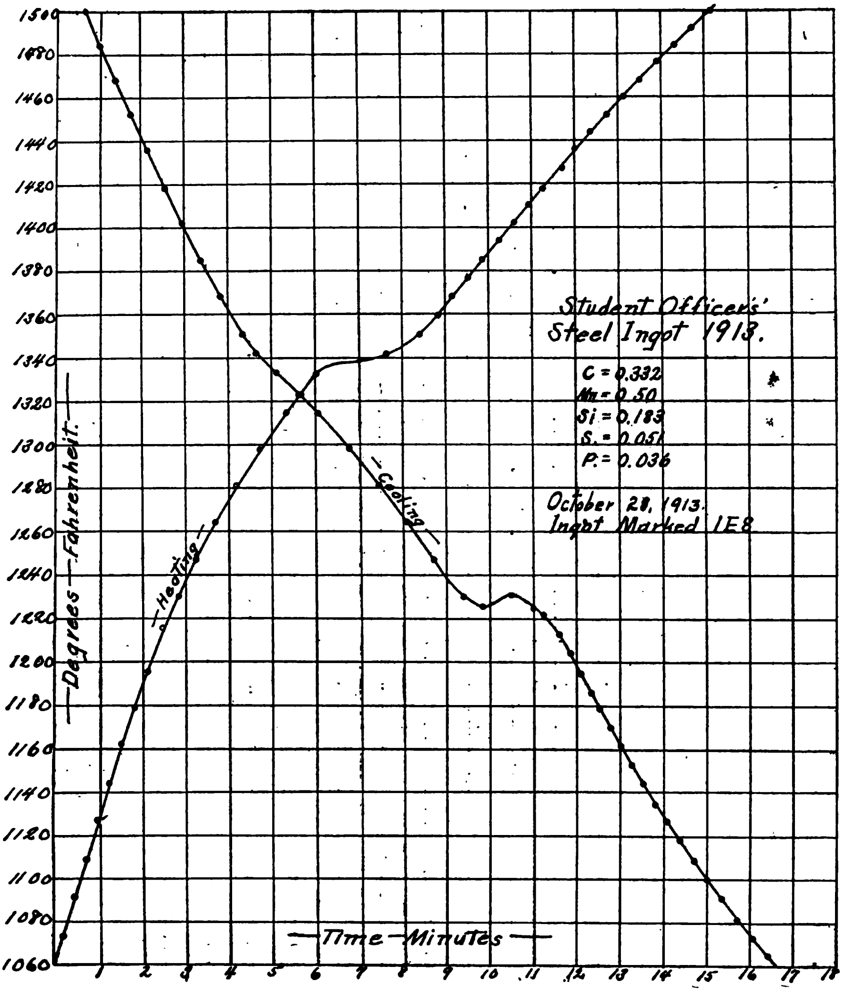


FIG. 28.

Cast steel. Heat treatment same as above.
Elastic limit, [illegible] pounds per square inch.
Tensile strength, [illegible] pounds per square inch.
Elongation, [illegible] per cent.
Contraction, [illegible] per cent.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Student Officers'
Steel Ingot 1913.
C = 0.332
Mn = 0.50
Si = 0.183
S. = 0.051
P. = 0.036
October 28, 1913.
Ingot Marked IE8

CRITICAL TEMPERATURES OF NICKEL AND CHROMIUM STEELS.

A STUDY OF THE CRITICAL TEMPERATURES OF NICKEL AND CHROMIUM STEELS.

The object of this experiment was to determine the effect of varying additions of nickel or chromium on the critical temperatures of steel of about the following composition:

	Per cent.
C	0.50
Mn	.50
Si	.15
S	less than .05
P	less than .05

Steel was taken from the Tropenas converter, the composition being obtained by the addition of ferromanganese, ferrosilicon, and washed metal in the ladle.

For the nickel steels, the additions of nickel were preheated in clay-lined crucibles. Thirty pounds of the molten steel, composition given above, were then poured into each crucible.

For the chrome steels pure metallic chromium was preheated, and the molten metal poured over it as before. It was found, however, that the chromium would not go into solution, but floated to the top with the slag. The desired chromium steel was finally obtained by heating in a clay-lined crucible ferromanganese, ferrosilicon, washed metal, and chromium with low-carbon boiler punchings until the whole was in a molten condition. After holding for one and one-half hours at furnace temperature the steel was poured.

The mold used was made of cast iron 3 inches diameter and 6 inches long. A dry-sand collar was placed at the top of the mold in order that the pipe would form in this collar, thus giving sound steel in the 6-inch length. The resulting ingot was then forged to 1 inch diameter and samples 1 inch long were taken for the experiment.

These samples were heated in an electric resistance furnace, and the Ac_1 and Ar_1 points determined by the time temperature method.

The temperatures were determined by means of a platinum, platinum-rhodium thermo couple, connected to a cold junction, which in turn was connected to a Leeds & Northrup precision potentiometer, which insured great accuracy in measuring temperatures. By use of a conversion table, the voltage read on the potentiometer was changed over to degrees centigrade. The time intervals of cooling were measured by means of a stop watch. In every case we tried to heat and cool at the same rate, and the heating was carried up to approximately 860° C., from which cooling began.

Temperatures were plotted as ordinates against times of cooling as abscissæ, and the point at which the break came in the curve was taken at the critical point. Such curves are shown in plates No. III to No. XXII. The following tables show the results obtained:

No. of specimen.	Per cent nickel.	Temperature of Ac_1.	Temperature of Ar_1.	Ac_1-Ar_1.
0	0.0	740	672	68
1	0.59	739	667	72
2	0.825	739	653	86
3	1.49	732	646	86
4	2.20	714	623	81
5	2.38	706	613	93
8	3.02	703	578	125
10	3.78	692	563	129
7	3.80	693	559	134
9	3.82	699	584	115

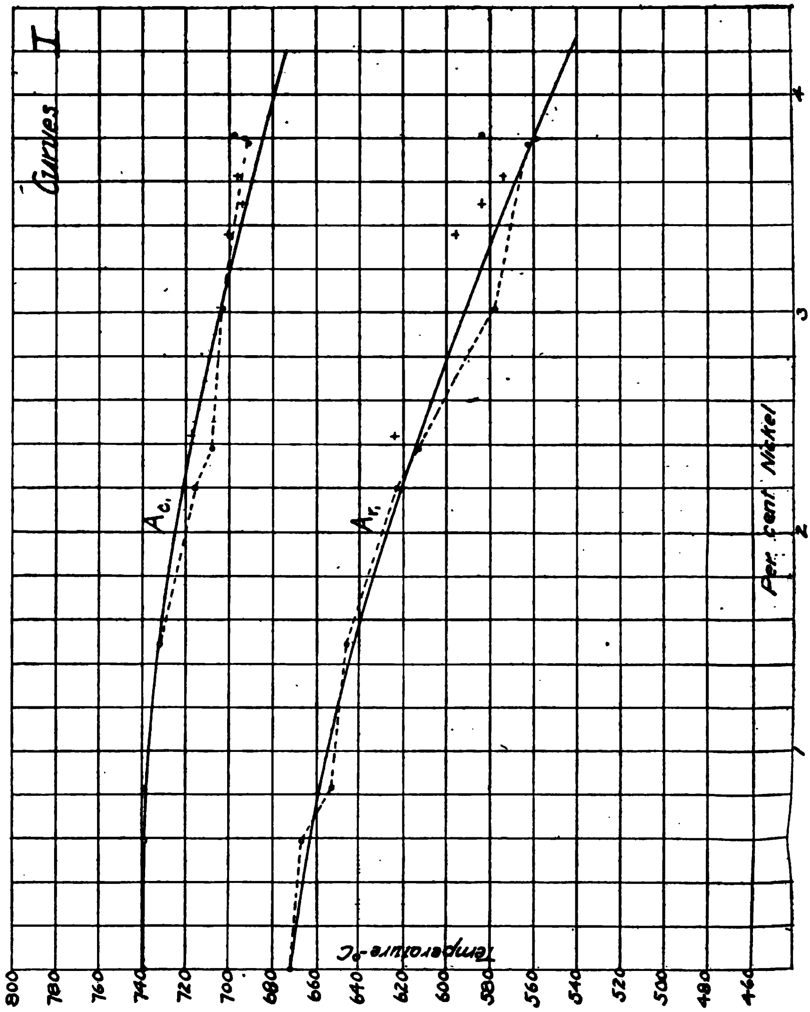
No. of specimen.	Per cent chromium.	Temperature of Ac_1.	Temperature of Ar_1.	Ac_1-Ar_1.
12	0.27	743	671	72
11	0.41	743	672	71
15	0.48	738	666	72
14	0.71	723	661	62
14A	0.815	754	686	68
15A	1.01	761	690	71
19	1.35	758	699	59
15B	2.71	789	737	52
16B	2.92	785	748	39
18B	3.48	794	737	47
19B	4.05	791	748	43

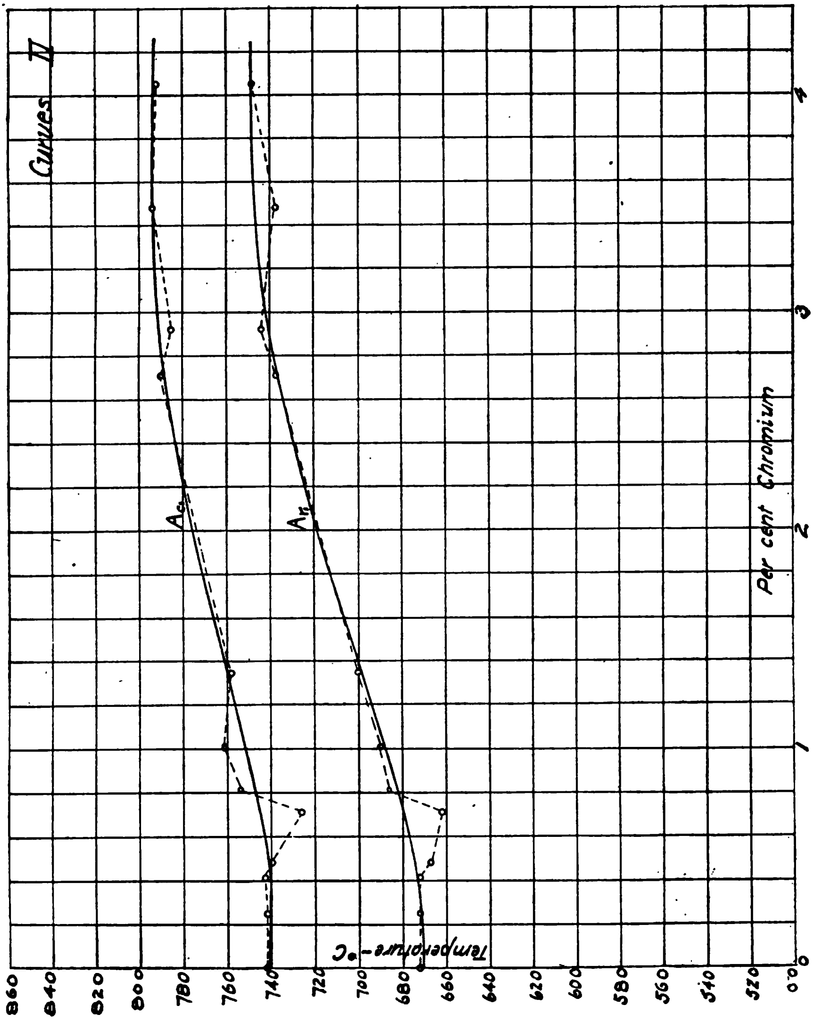
Plot No. I shows the curves formed by plotting temperatures as ordinates against per cents nickel as abscissæ. Plot No. II shows temperature plotted against per cent chromium. The dotted lines show the true curves while the solid lines show the ideal curves.

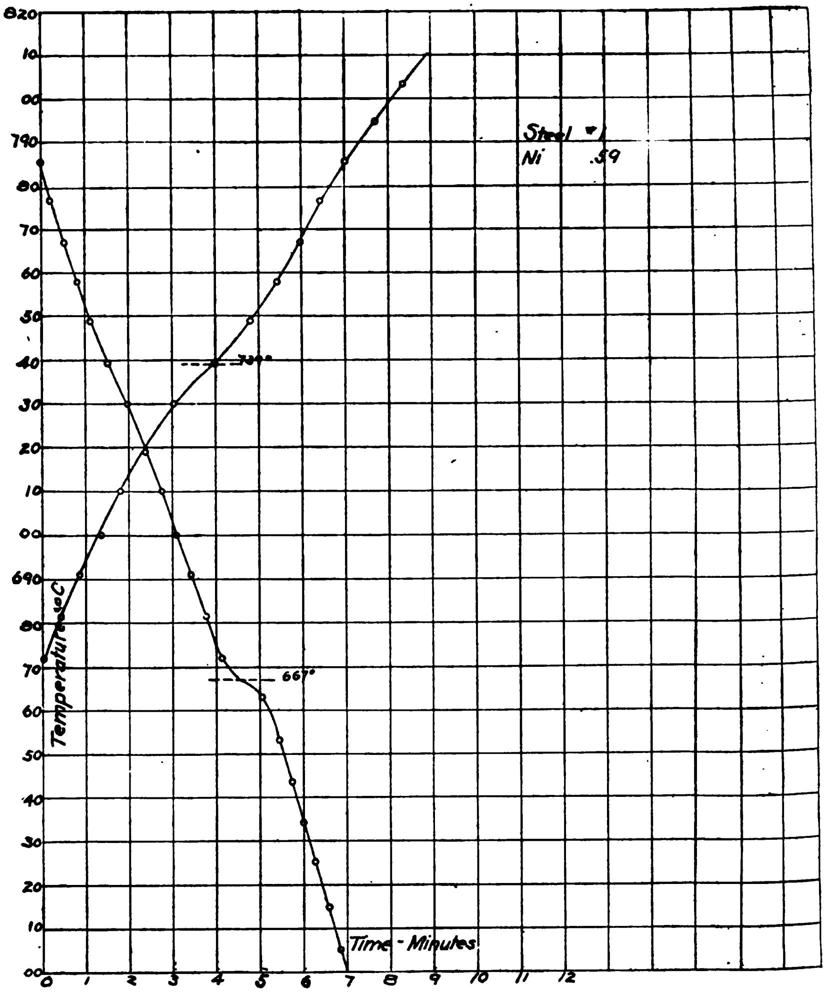
In plot No. I the crosses refer to critical points of nickel steels which were previously determined at the arsenal. It will be seen that these points lie extremely near the ideal curve and the deviation might well be due to experimental error.

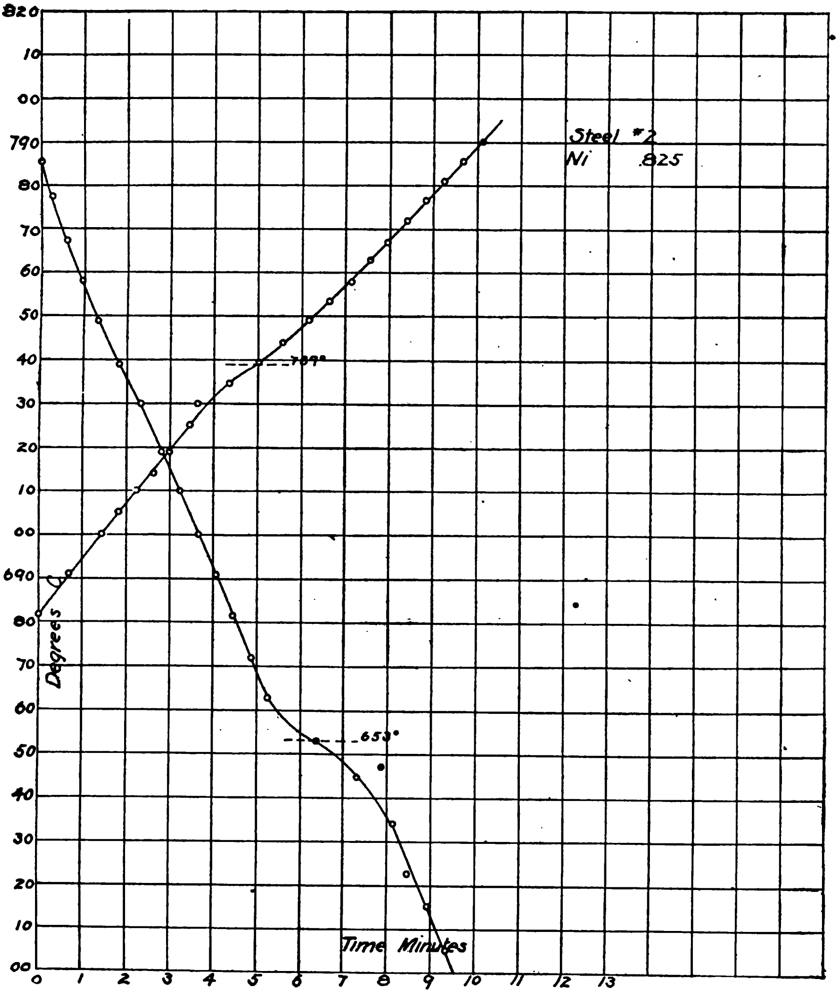
As a result of this investigation, it is concluded that as the nickel content of a steel increases up to 4 per cent, its critical temperature decreases; the critical temperature on cooling decreasing more rapidly than that on heating. Beyond 4.05 per cent no experimental data were obtained. Curves Ar_1 and Ac_1 on plot No. I show the results of varying per cents of nickel on the critical points.

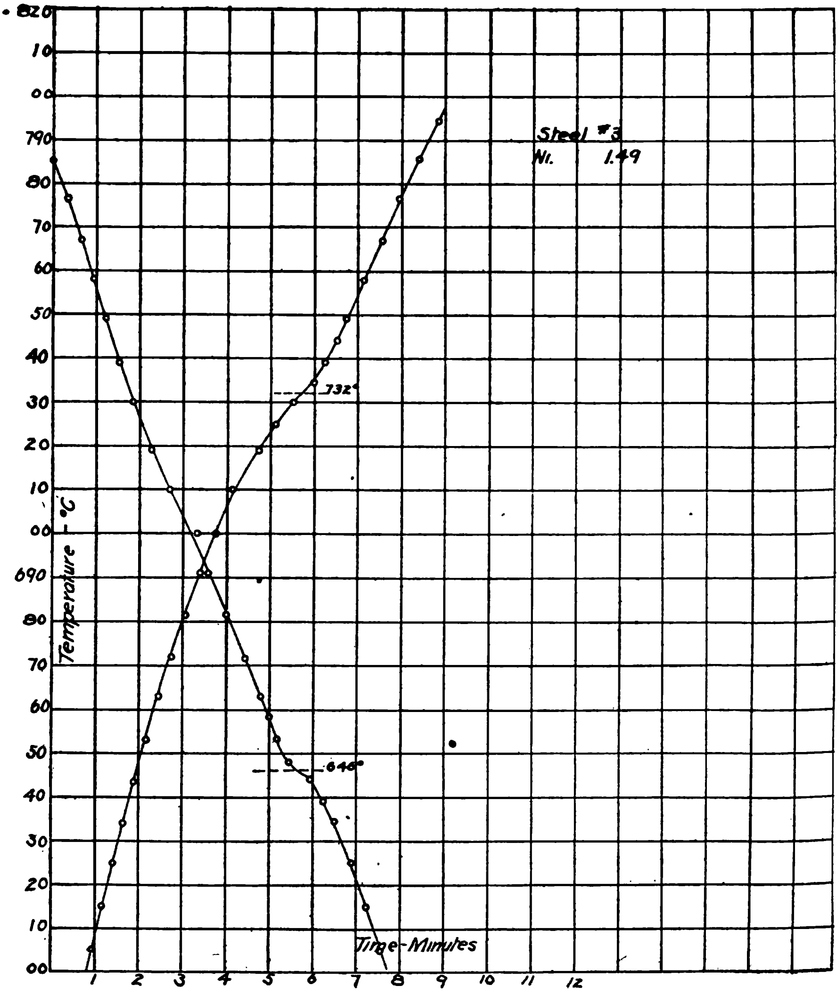
The investigations with chromium indicate that increasing the chromium content raises the critical temperature. The critical temperature on cooling rises more rapidly than that on heating. Plot No. II shows that the only inconsistent points are those where the chromium content is 0.71 per cent, and it is therefore assumed that this discrepancy is due to experimental error.

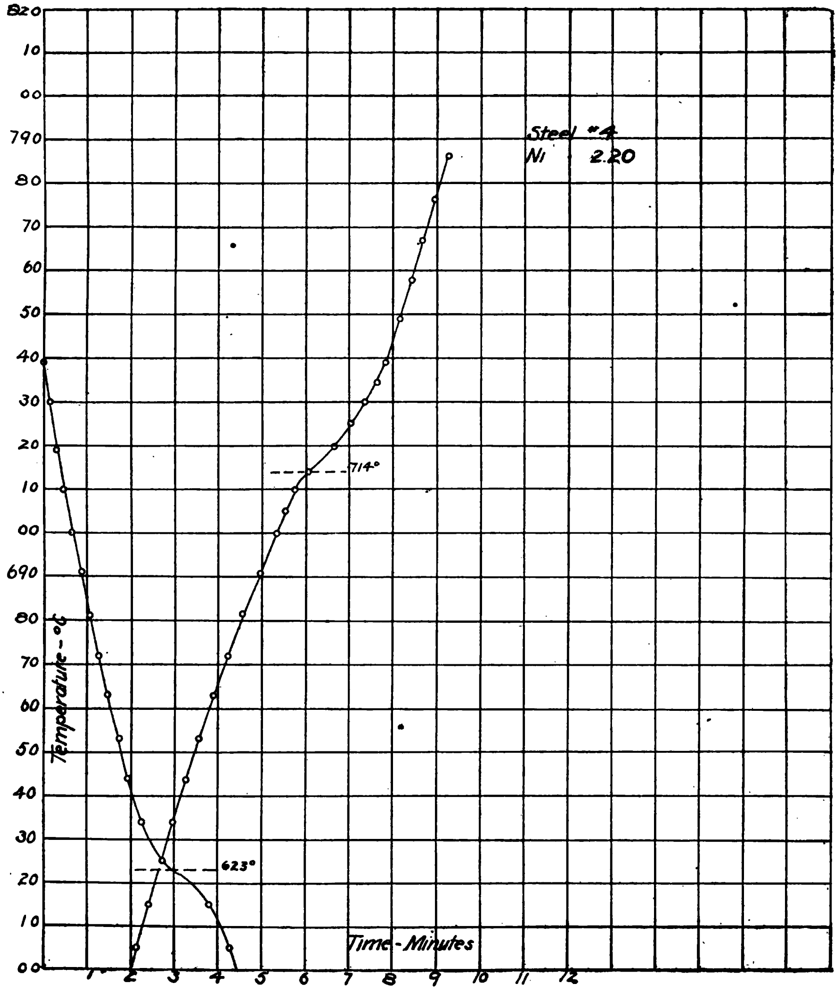

Curves I
Ac1
Ar1
Per cent Nickel
1
2
3
4
Temperature °C
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460

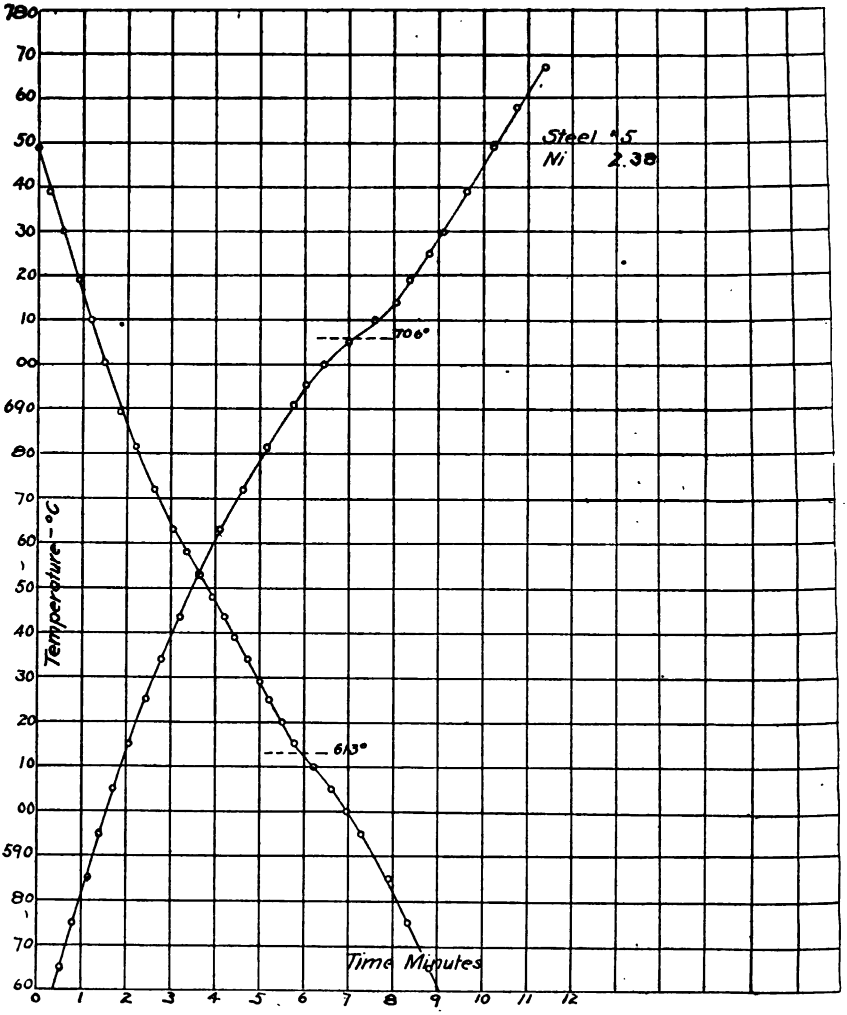

Curves IV
Ac
Ar
Per cent Chromium
0
1
2
3
4
Temperature - °C
860
840
820
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
0.0

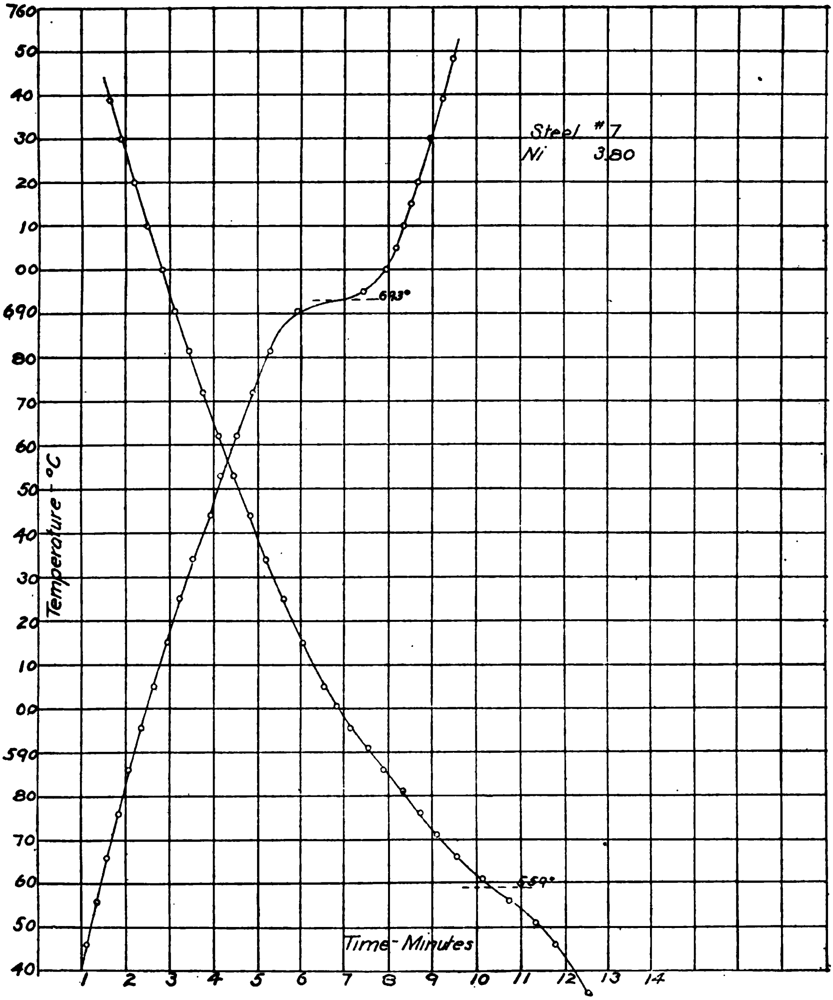

820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature °C
Time - Minutes
0
1
2
3
4
5
6
7
8
9
10
11
12
739°
667°
Steel #1
Ni .59

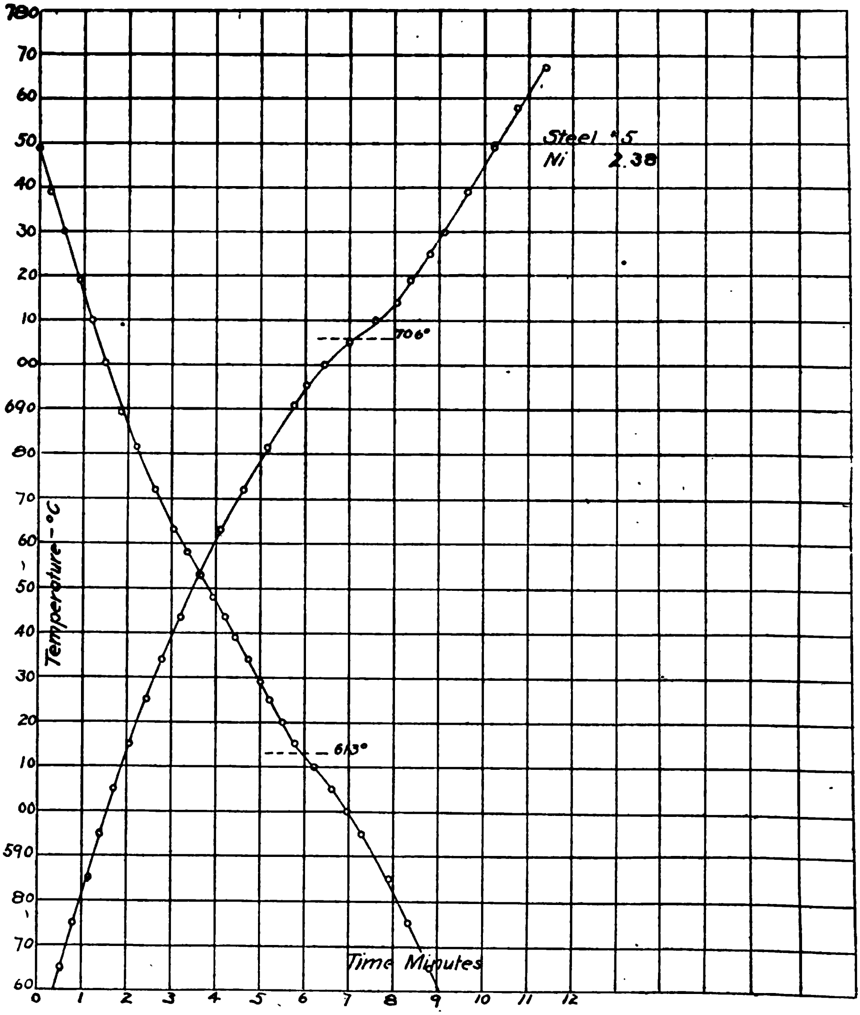

Steel #2
Ni .825
739°
653°
820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Degrees
Time Minutes
0
1
2
3
4
5
6
7
8
9
10
11
12
13

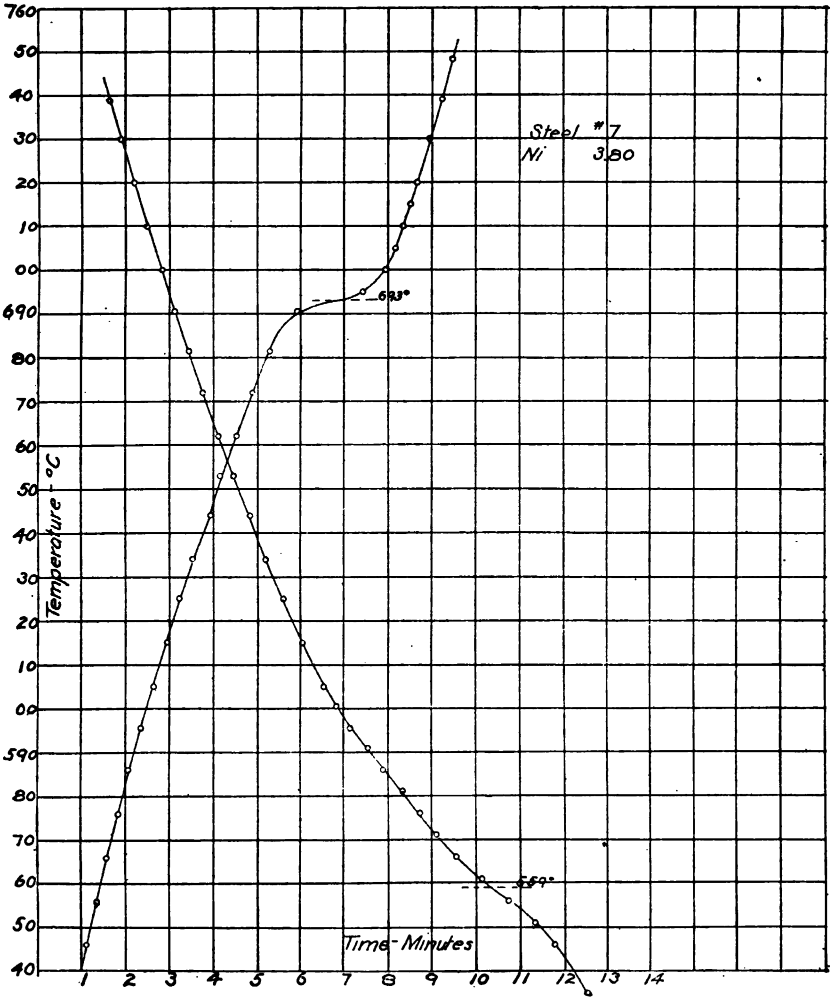

820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature - °C
Steel #3
Ni. 1.49
732°
646°
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12

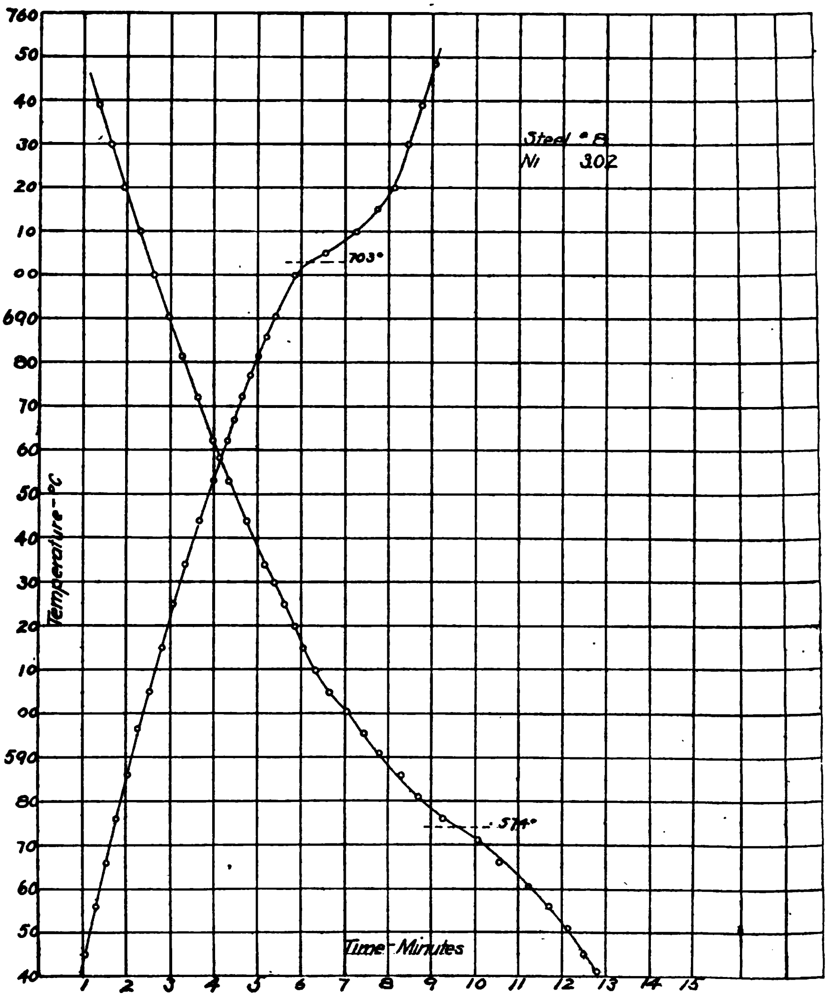

820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature - °C
1
2
3
4
5
6
7
8
9
10
11
12
Time-Minutes
Steel #4
Ni 2.20
714°
623°


780
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
Temperature - °C
0
1
2
3
4
5
6
7
8
9
10
11
12
Time Minutes
Steel #5
Ni 2.38
706°
613°

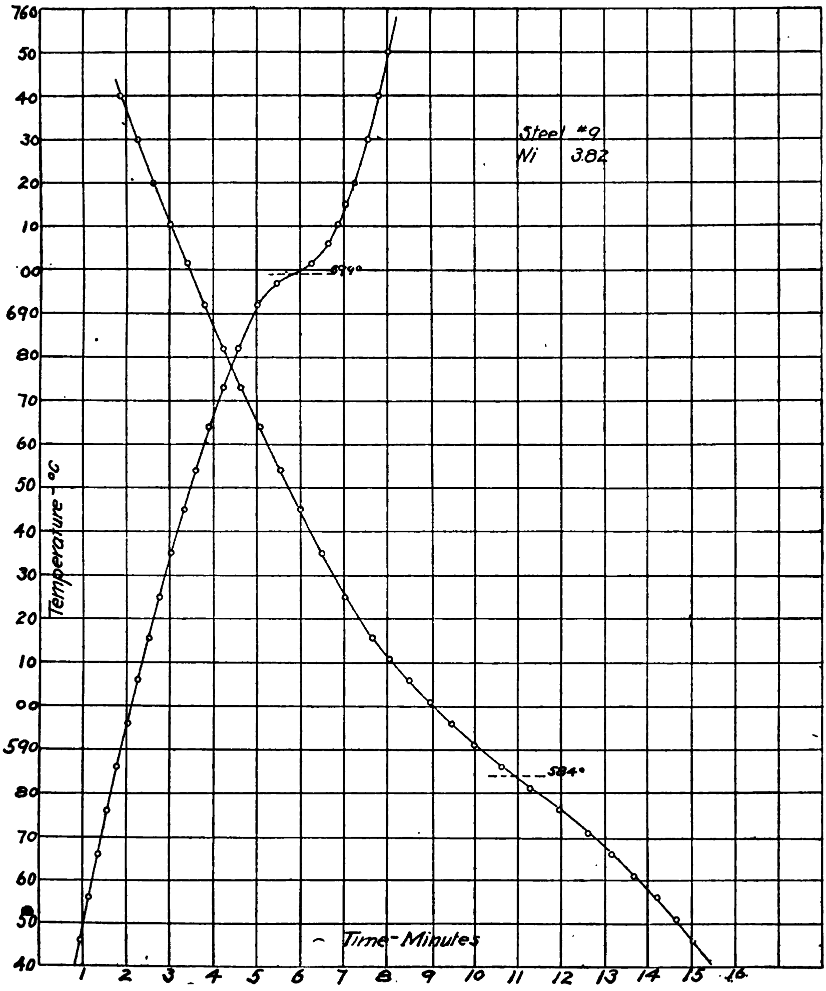

760
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
50
40
Temperature - °C
Steel #7
Ni 3.80
693°
559°
Time - Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14


780
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
Temperature – °C
Steel °5
Ni 2.38
706°
613°
Time Minutes
0
1
2
3
4
5
6
7
8
9
10
11
12

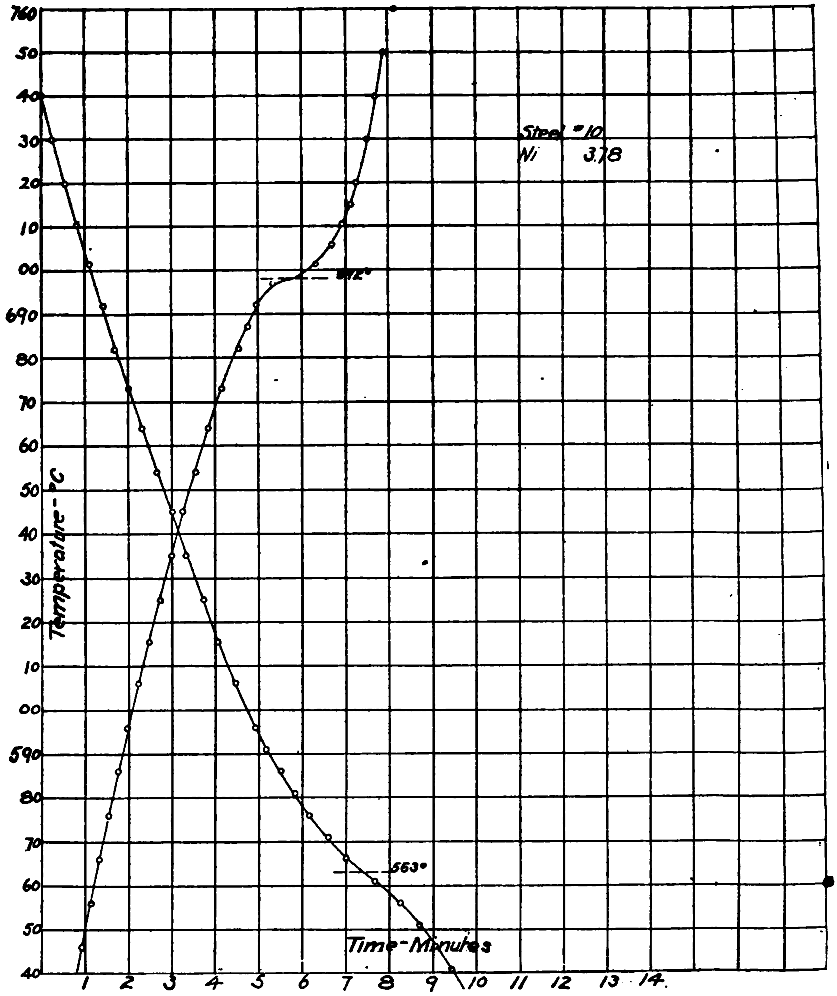

Steel #7
Ni 3.80
693°
559°
Temperature - °C
Time - Minutes
760
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14


760
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
50
40
Temperature - °C
Steel ° B
Ni 302
703°
574°
Time - Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

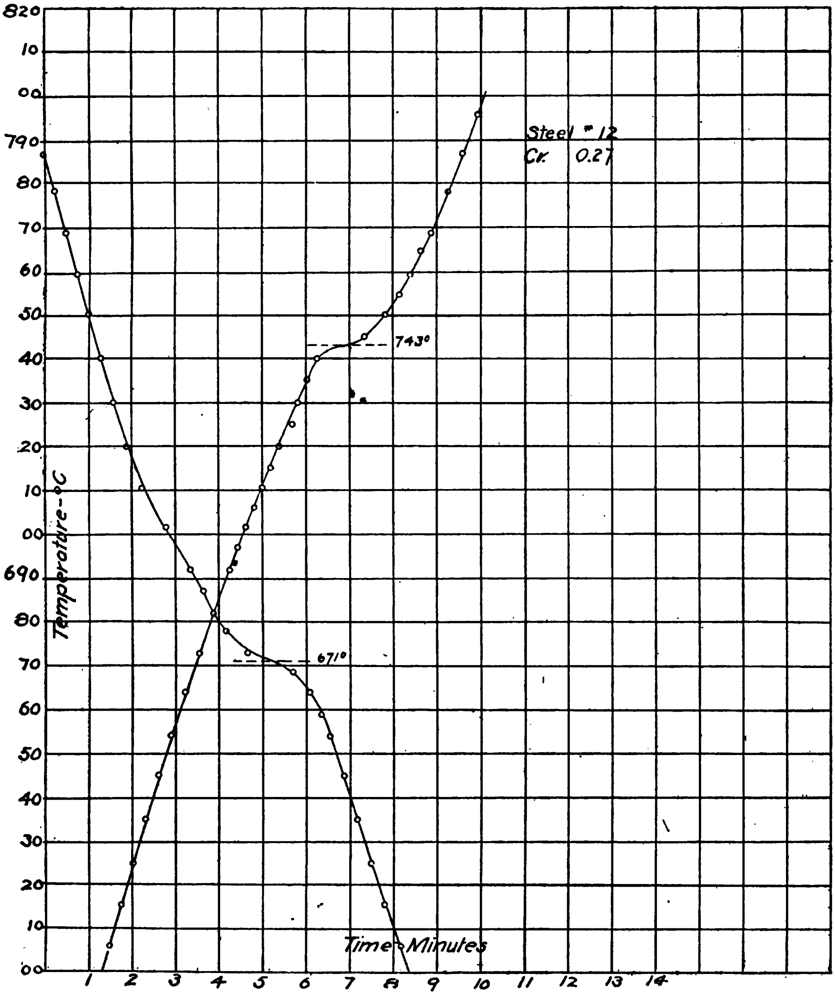
CURVES IX.


Steel #9
Ni 3.82
694°
584°
Temperature - °C
Time-Minutes
760
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

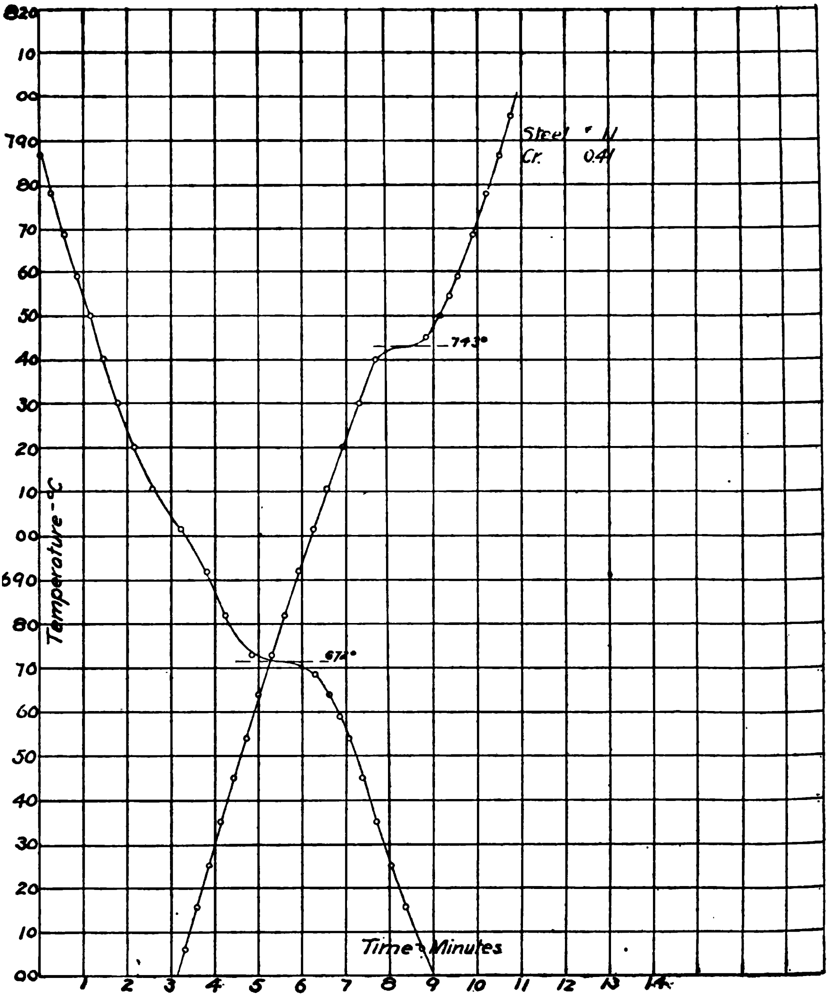
CURVES X


760
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
590
80
70
60
50
40
Temperature - °C
Steel #10
Ni 3.78
692°
563°
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14

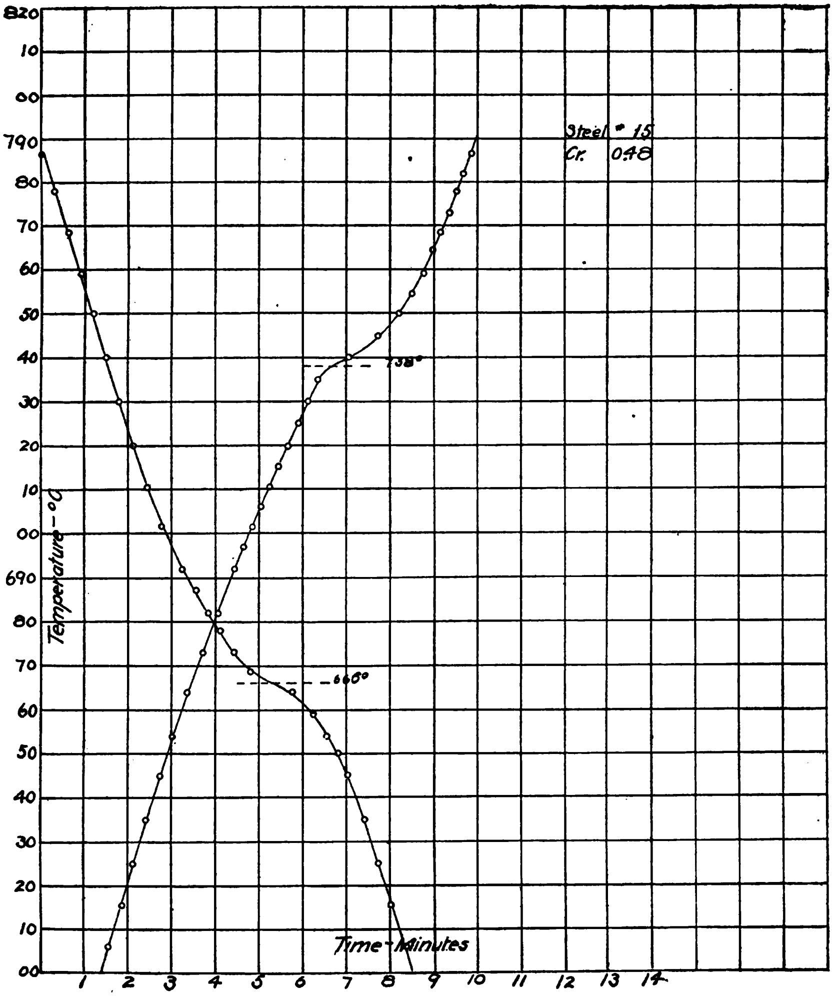
CURVES XI.


820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature-°C
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Steel # 12
Cr. 0.27
743°
671°

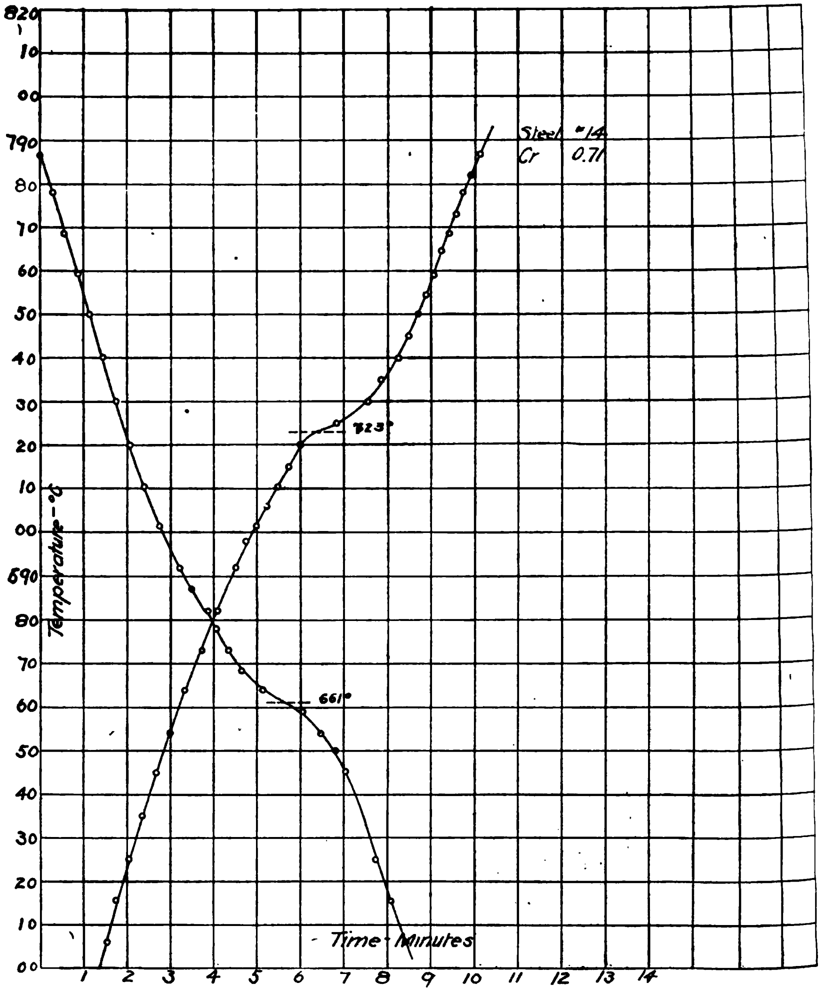
CURVES XII.


820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature - C
Steel N
Cr. 0.41
743°
672°
Time - Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14

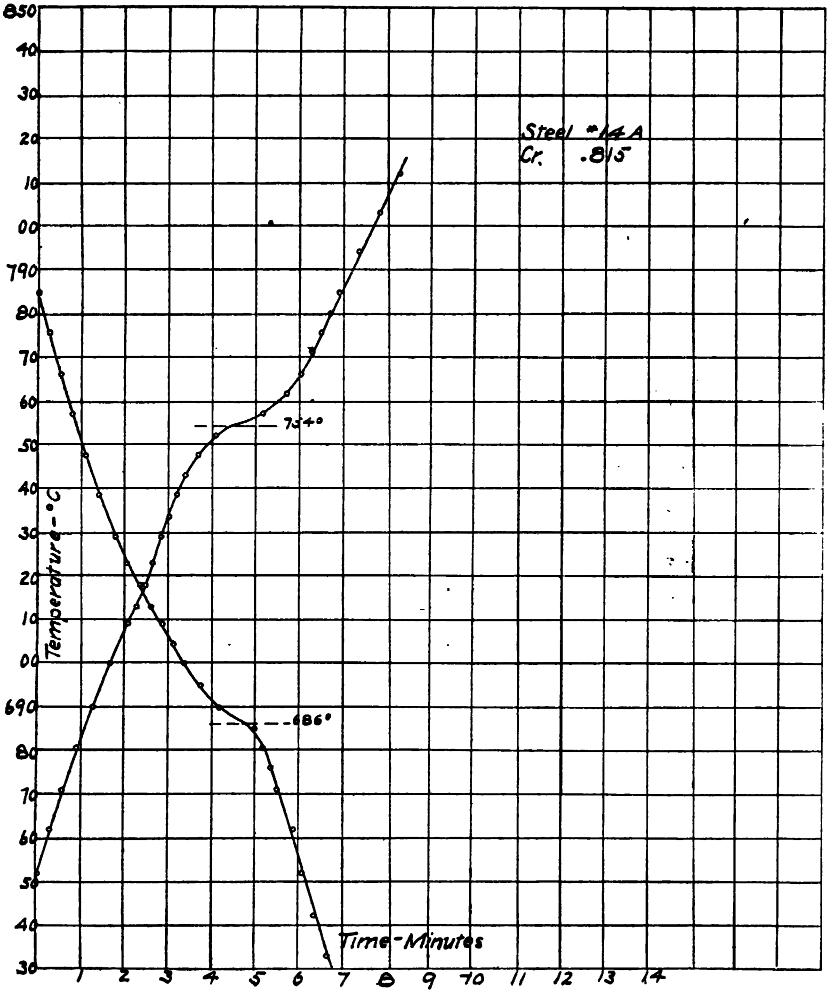
CURVES XIII.


820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
Temperature – °C
Steel * 15
Cr. 0.48
738°
666°
Time – Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14

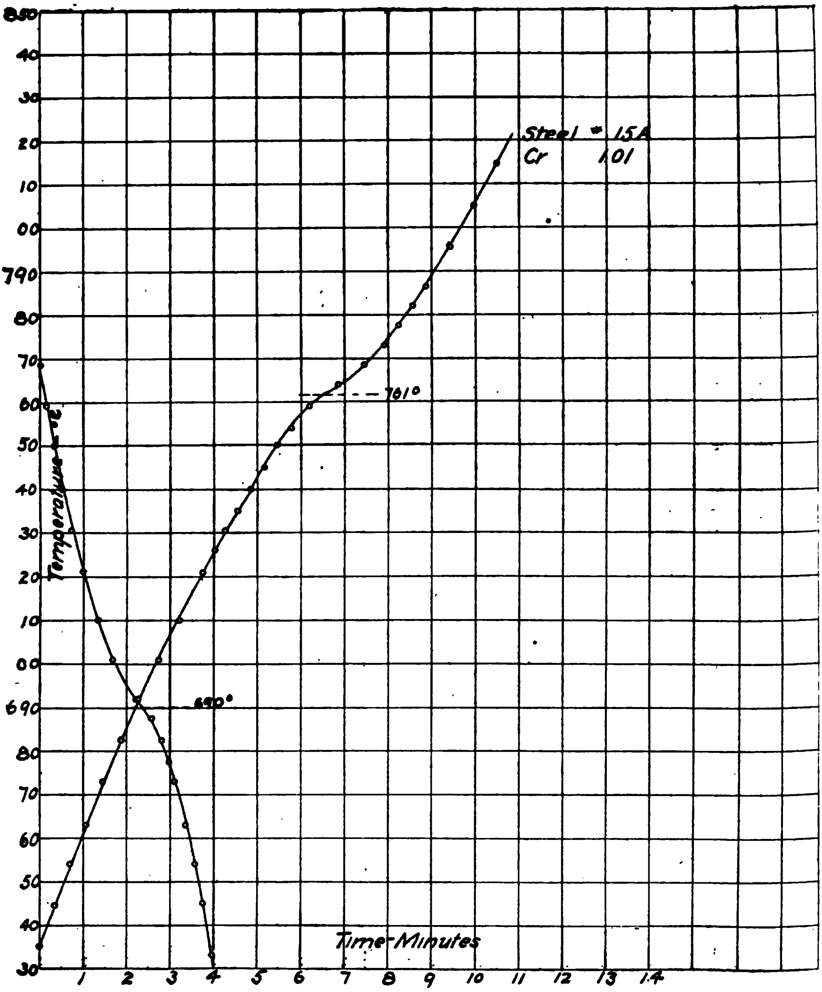
CURVES XIV.


820
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
20
10
00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Temperature – °C
Time – Minutes
Steel #14
Cr 0.71
723°
661°

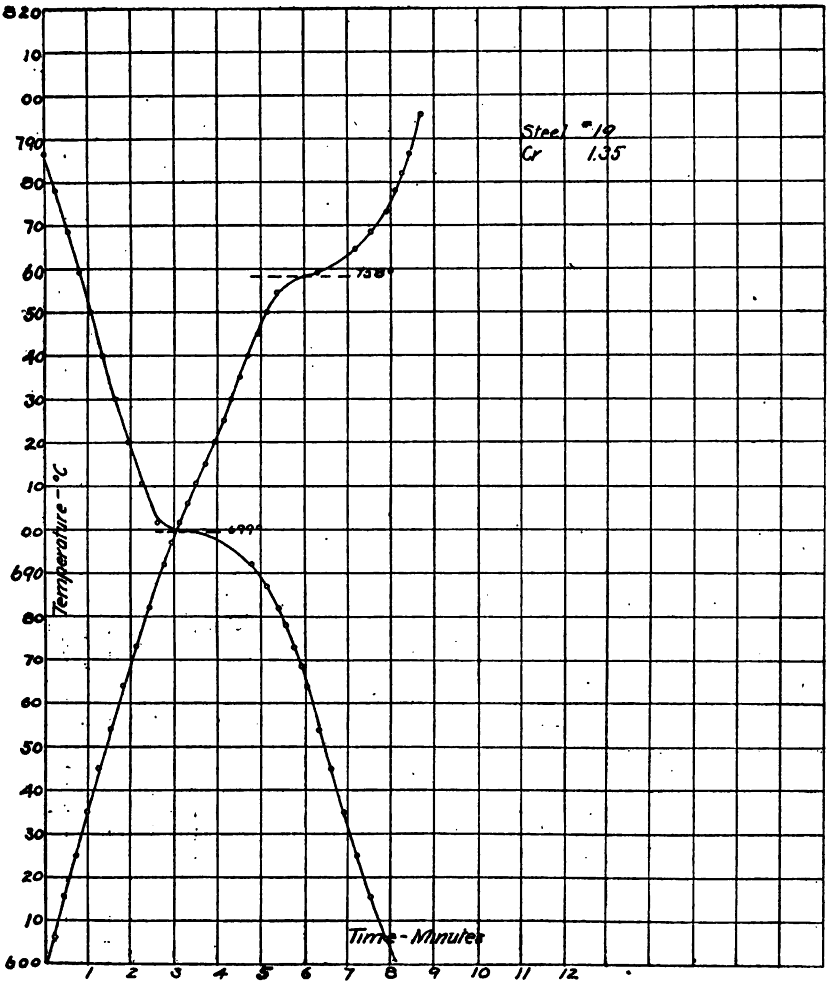
CURVES XV.


Steel #14A
Cr. .815
754°
686°
Temperature - °C
Time-Minutes
850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14

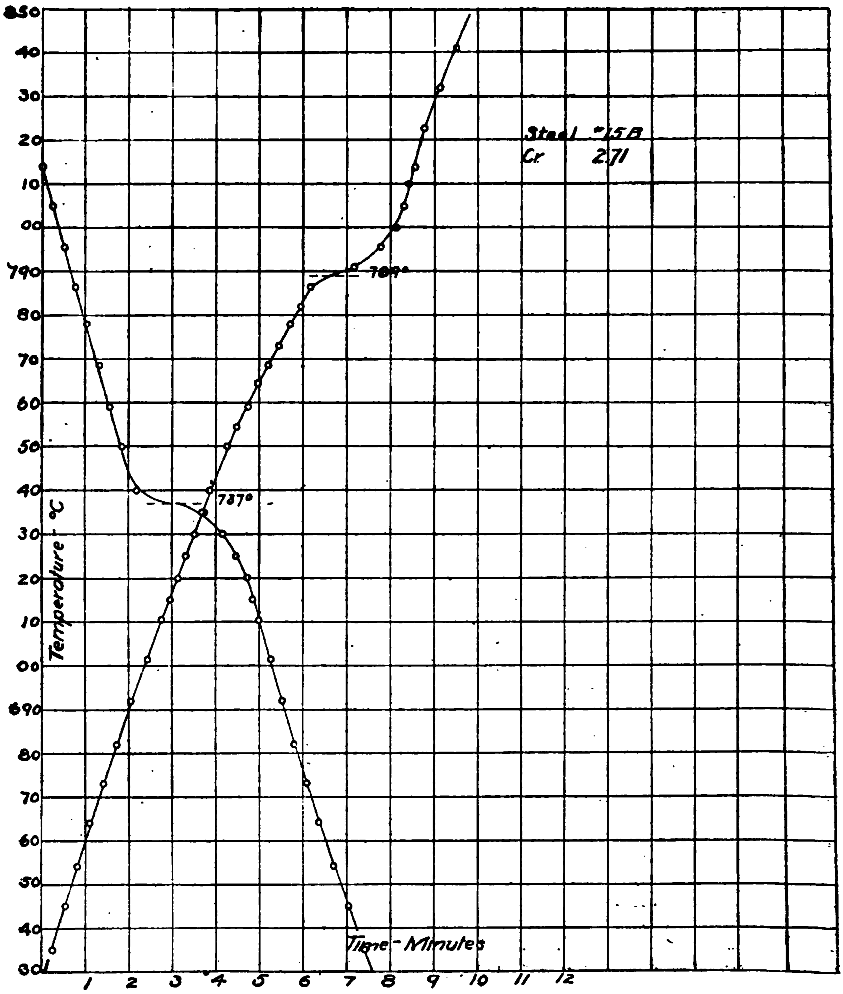
CURVES XVI.


850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
Temperature °C
Steel # 15A
Cr 1.01
761°
690°
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14

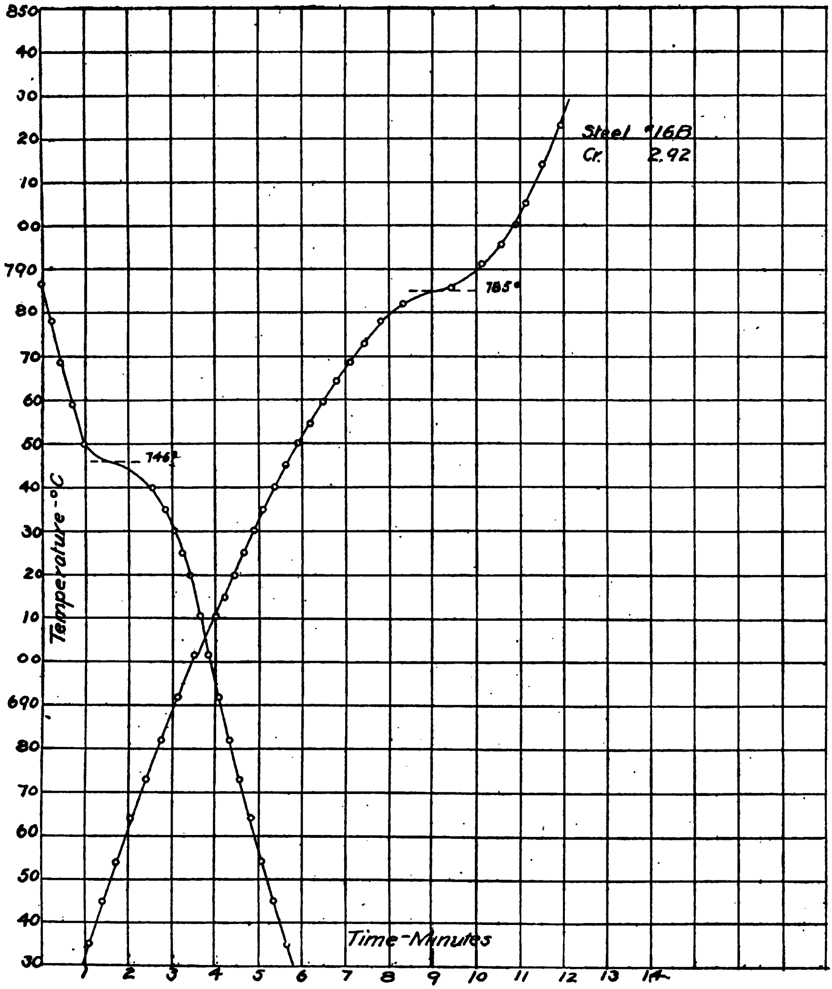
CURVES XVII.



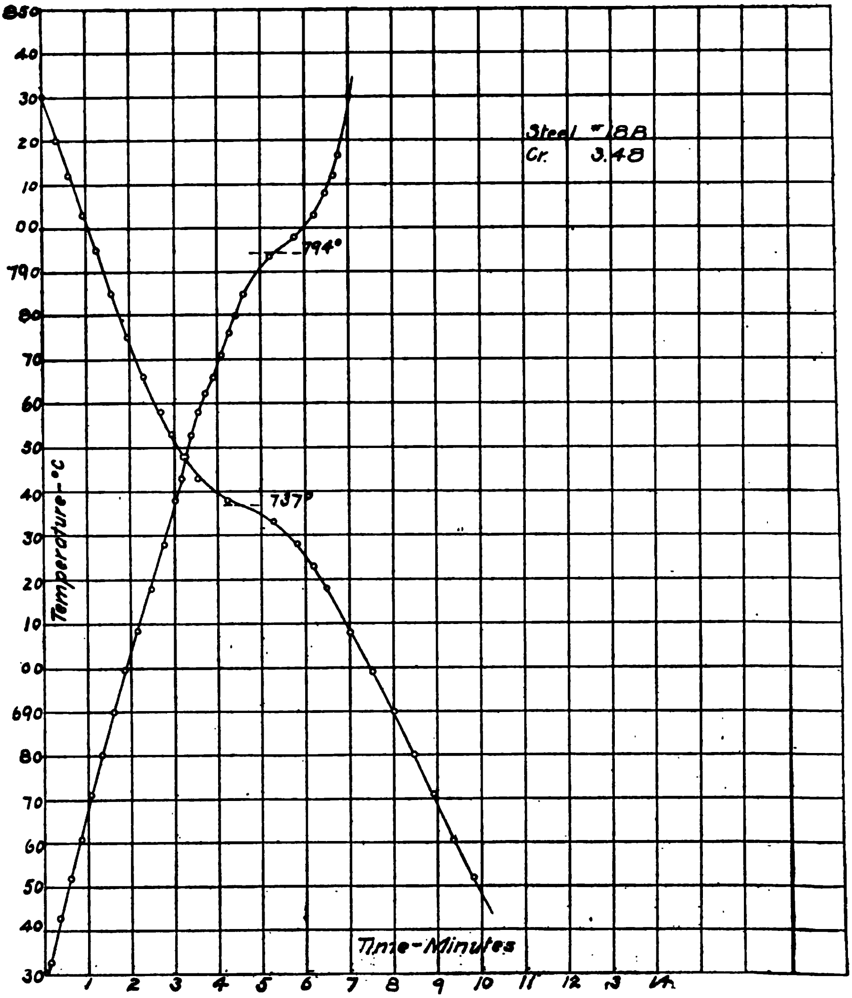
CURVES XVIII.


850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
Temperature - °C
789°
787°
Steel #15B
Cr 2.71
Time - Minutes
1
2
3
4
5
6
7
8
9
10
11
12

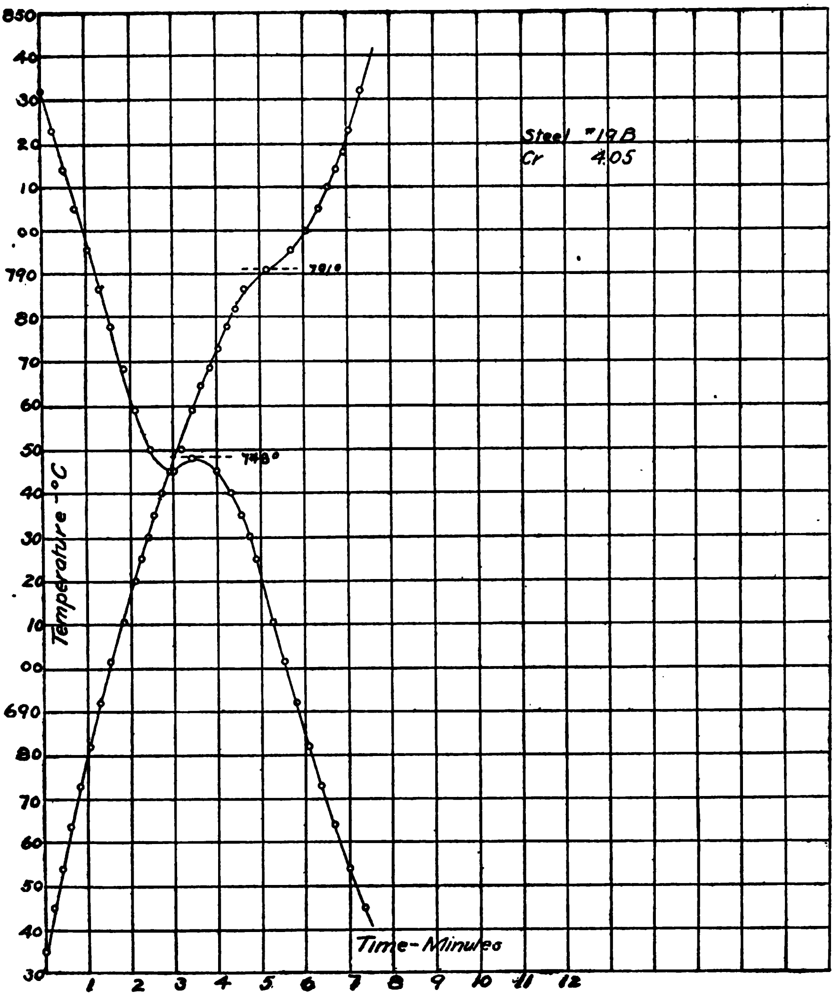
CURVES XIX.


850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
Temperature-°C
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
746°
785°
Steel #16B
Cr. 2.92

CURVES XX.


850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
Temperature - °C
Time - Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
794°
737°
Steel #188
Cr. 3.48

CURVES XXI.


850
40
30
20
10
00
790
80
70
60
50
40
30
20
10
00
690
80
70
60
50
40
30
Temperature °C
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
791°
748°
Steel #19B
Cr 4.05

CURVES XXII.

PYROMETRY.

PYROMETRY.

Thermocouples are used at Watertown Arsenal for the measurement of high temperatures.

The principle of the thermocouple is "the junction of two metals heated to a given temperature is the seat of an electromotive force which is a function of the temperature only."[1]

The electromotive force thus developed is measured by a potentiometer.

For laboratory and experimental work rare metal couples of platinum and 90 per cent platinum plus 10 per cent rhodium are used, in connection with a Leeds & Northrup potentiometer, reading to 1 microvolt. The maximum instrumental error, therefore, is less than 1° C.

For calibration purposes the rare metal couples are checked against the freezing points of pure metals and salts. Curves for zinc, antimony, and salt (NaCl) are shown on pages 185 to 188.

The pyrometers are used to obtain the critical temperatures of different steels. Curves shown on pages 188 to 203 give the Ac_1 and Ar_1 points for the regular Ordnance Department cast and forged steels, also for some high carbon tool steels.

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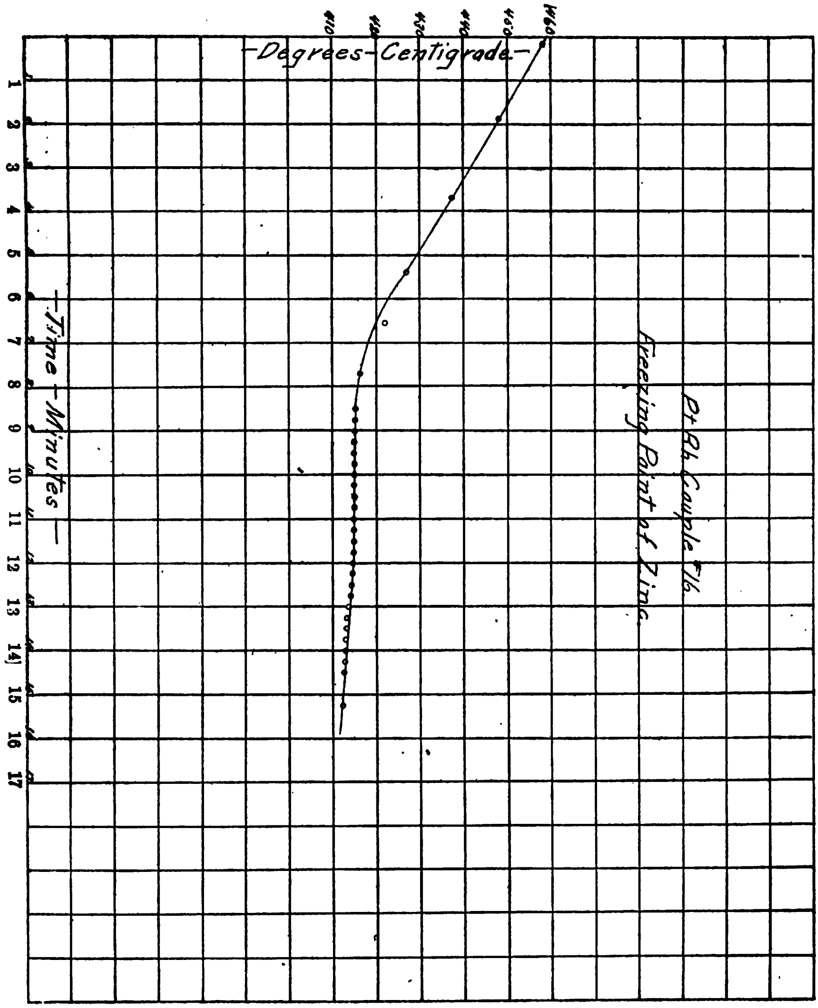
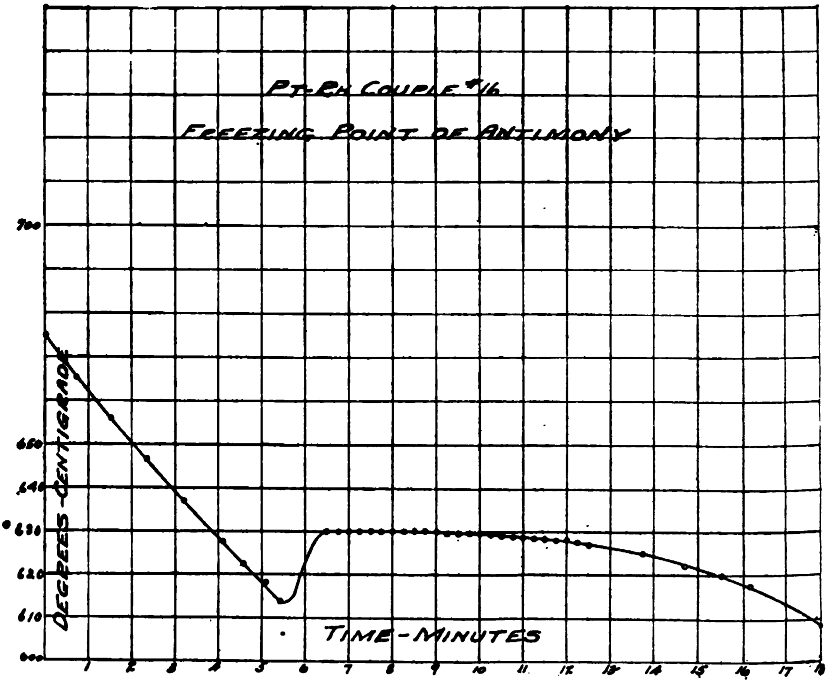
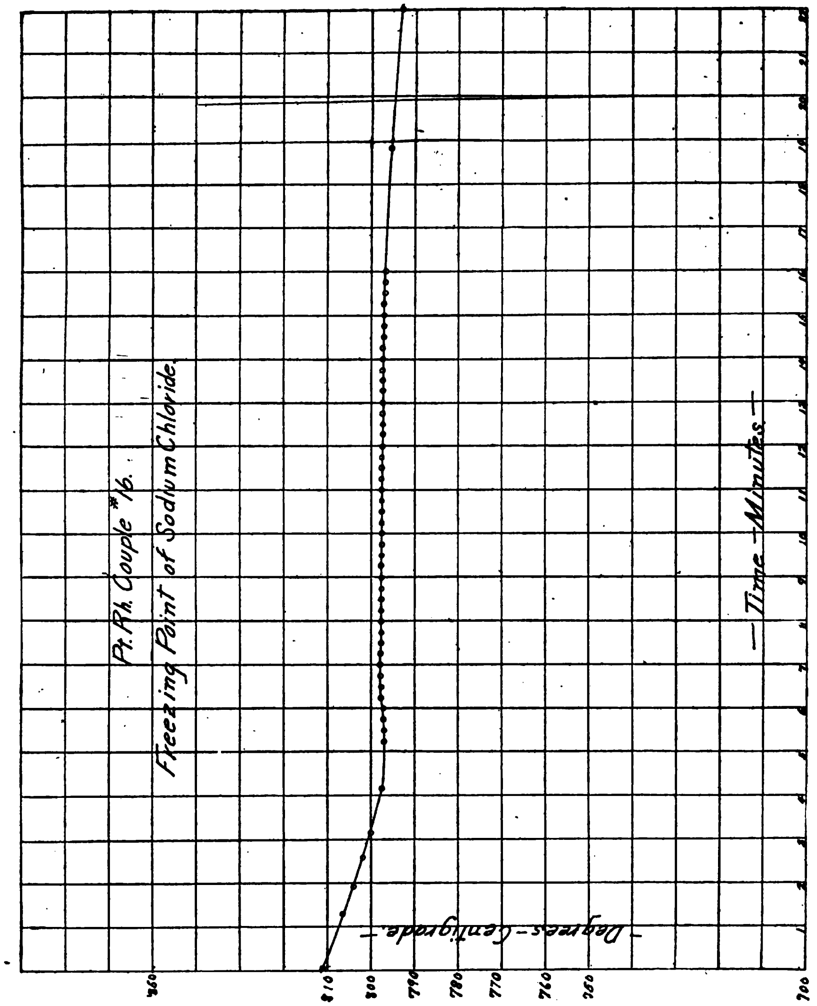
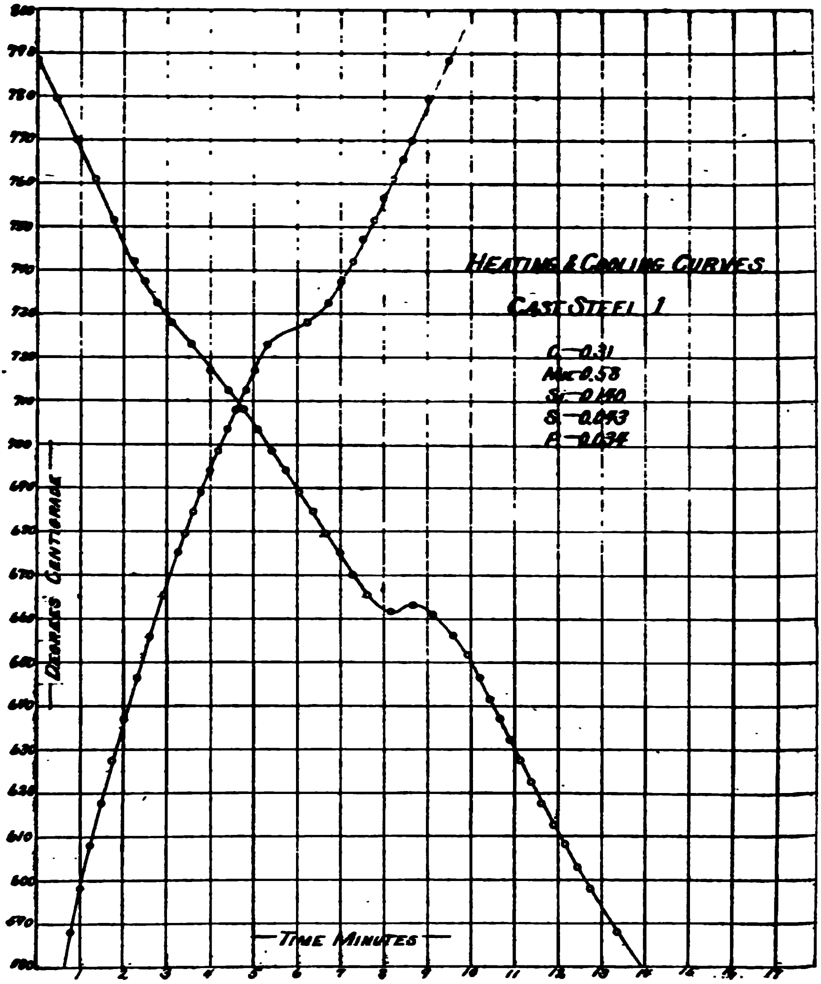
[1] Measurement of High Temperatures, Burgess & Le Chatelier.

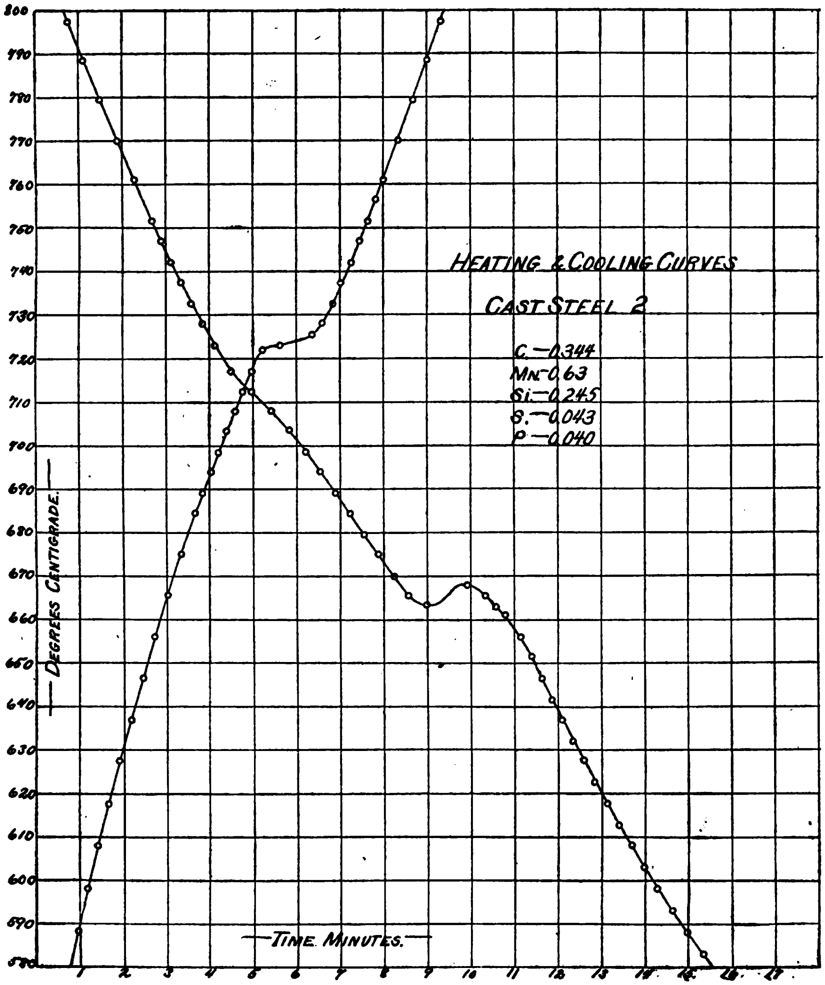


410
420
430
440
450
460
—Degrees—Centigrade—
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
—Time—Minutes—
Pt Rh Couple #16
Freezing Point of Zinc.


Pt-Rh Couple #16
Freezing Point of Antimony
Degrees-Centigrade
700
650
640
630
620
610
600
Time-Minutes
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18


Pt. Rh. Couple #16.
Freezing Point of Sodium Chloride.
— Time — Minutes —
— Degrees — Centigrade. —
850
810
800
790
780
770
760
750
700
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


HEATING & COOLING CURVES.
CAST STEEL 1
C—0.31
Mn—0.58
Si—0.140
S—0.043
P—0.034
DEGREES CENTIGRADE
TIME MINUTES
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17


HEATING & COOLING CURVES
CAST STEEL 2
C.—0.344
MN.—0.63
SI.—0.245
S.—0.043
P.—0.040
—DEGREES CENTIGRADE.—
—TIME. MINUTES.—
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
1
2
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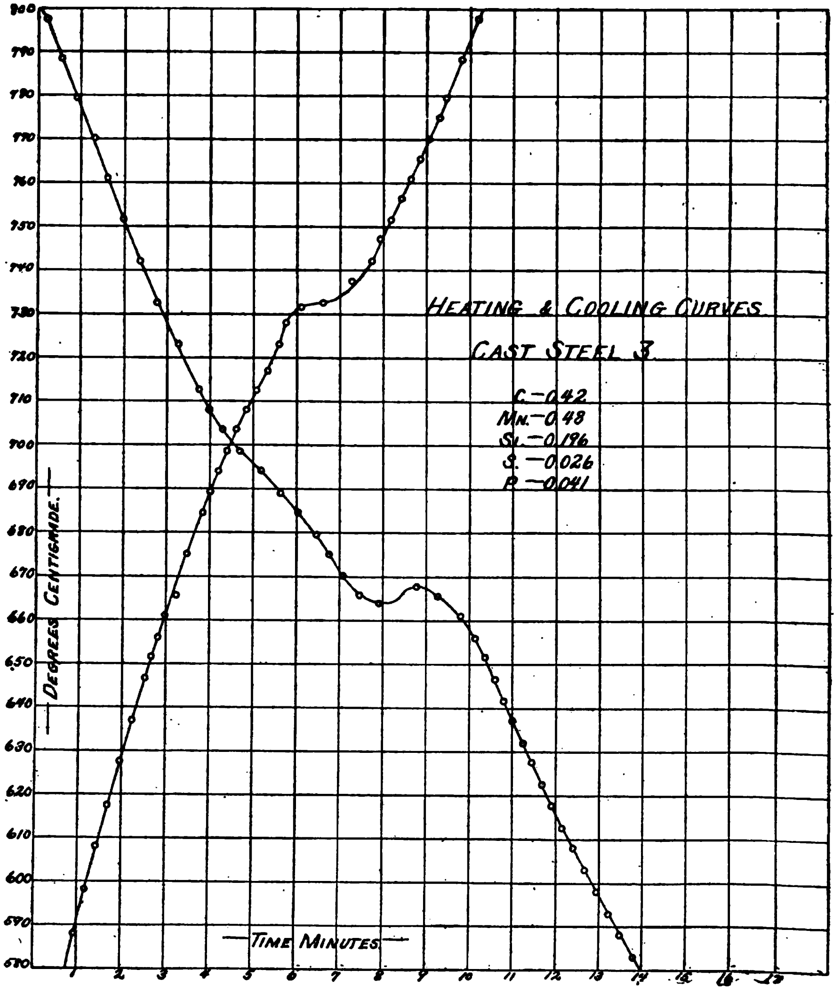
HEATING & COOLING CURVES.
CAST STEEL 3.
C.—0.42
MN.—0.48
SI.—0.196
S.—0.026
P.—0.041
DEGREES CENTIGRADE.
TIME MINUTES.
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
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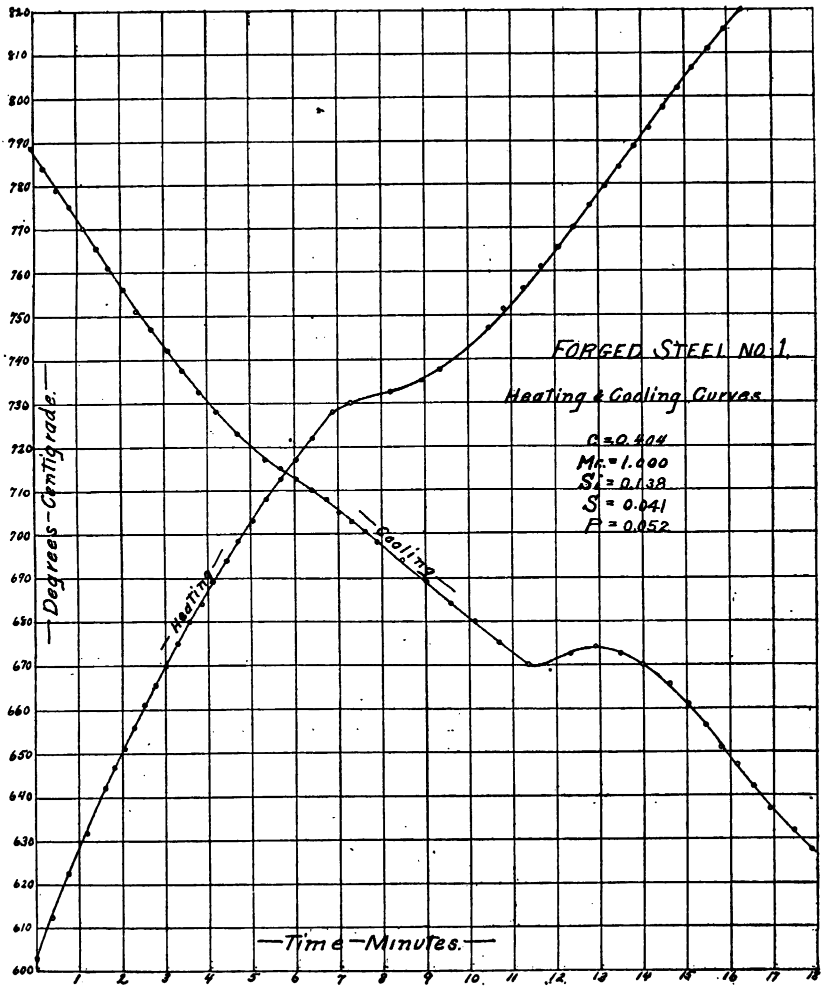
FORGED STEEL NO. 1.
Heating & Cooling Curves.
C = 0.404
Mn. = 1.000
Si = 0.138
S = 0.041
P = 0.052
— Degrees-Centigrade. —
— Time — Minutes. —
— Heating —
— Cooling —
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
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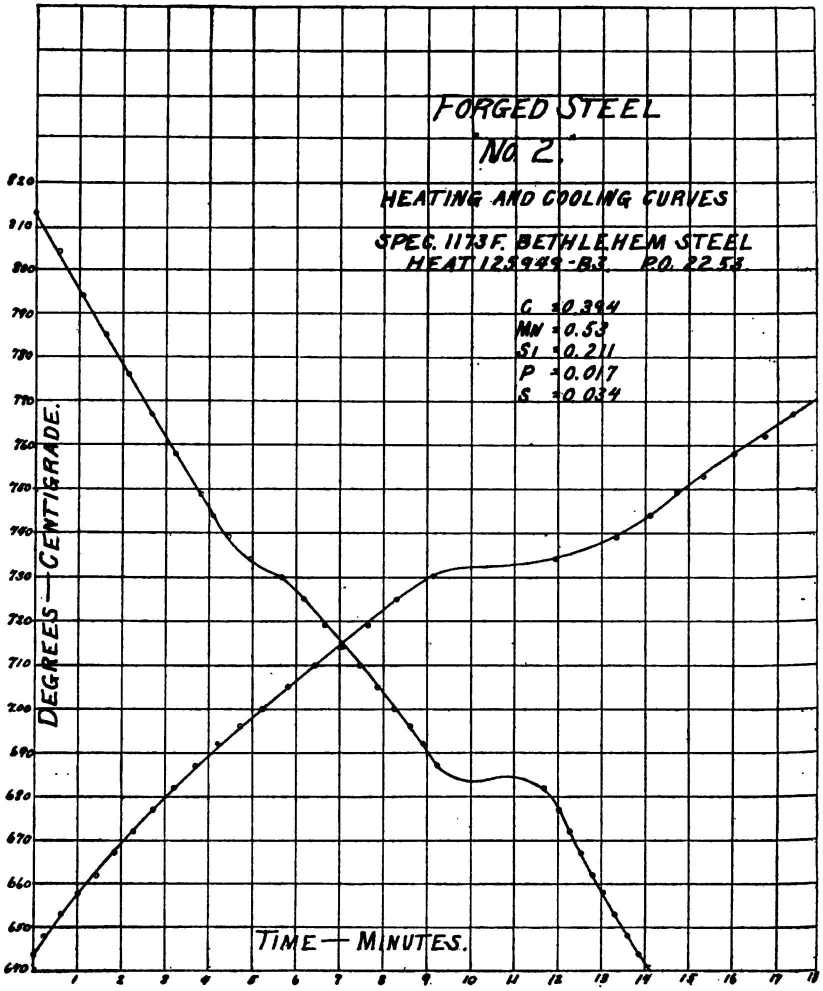
18


FORGED STEEL
"NO. 2."
HEATING AND COOLING CURVES
SPEC. 1173F. BETHLEHEM STEEL
HEAT 125949-B.3. P.O. 2253.
C =0.394
MN =0.53
SI =0.211
P =0.017
S =0.034
DEGREES—CENTIGRADE.
TIME—MINUTES.
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
1
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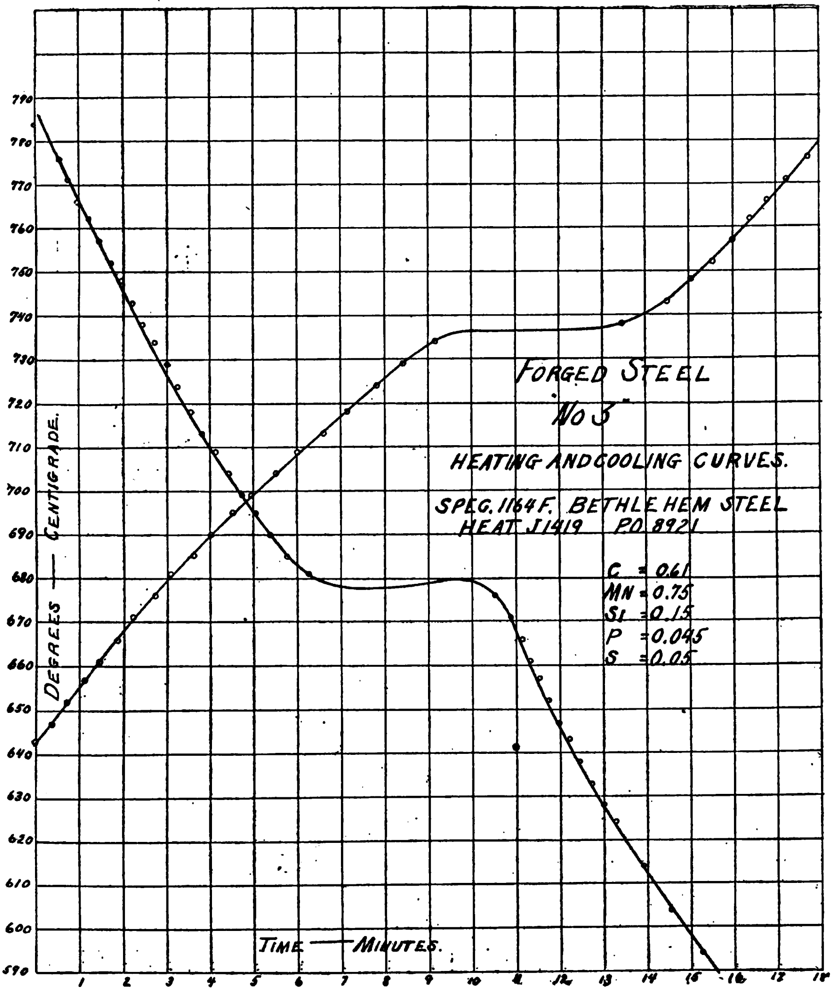
18


FORGED STEEL
No 3
HEATING AND COOLING CURVES.
SPEC. 1164 F. BETHLEHEM STEEL
HEAT J1419 PO 8921
C = 0.61
MN = 0.75
SI = 0.15
P = 0.045
S = 0.05
DEGREES — CENTIGRADE.
TIME — MINUTES.
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
1
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3
4
5
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7
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9
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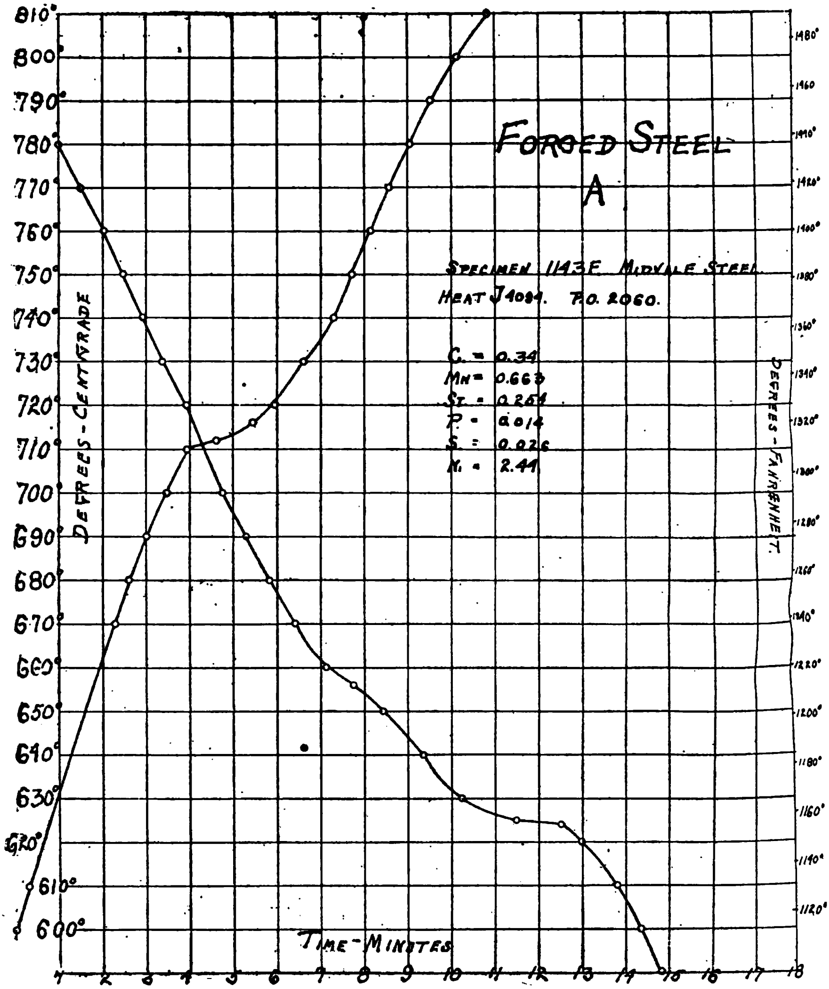
11
12
13
14
15
16
17
18


FORGED STEEL
A
SPECIMEN 1143F MIDVALE STEEL
HEAT J4094. P.O. 2060.
C. = 0.34
MN = 0.663
SI. = 0.254
P. = 0.014
S. = 0.026
NI = 2.44
DEGREES - CENTIGRADE
DEGREES - FAHRENHEIT.
TIME - MINUTES
810°
800°
790°
780°
770°
760°
750°
740°
730°
720°
710°
700°
690°
680°
670°
660°
650°
640°
630°
620°
610°
600°
1480°
1460°
1440°
1420°
1400°
1380°
1360°
1340°
1320°
1300°
1280°
1260°
1240°
1220°
1200°
1180°
1160°
1140°
1120°
1
2
3
4
5
6
7
8
9
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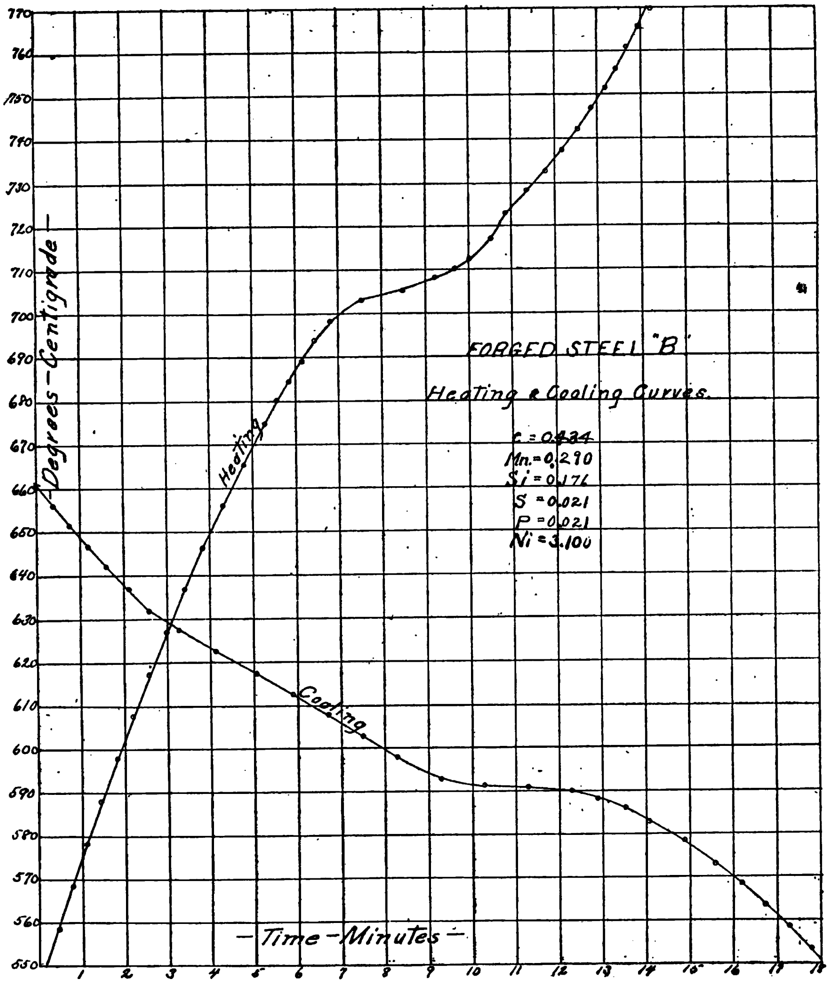
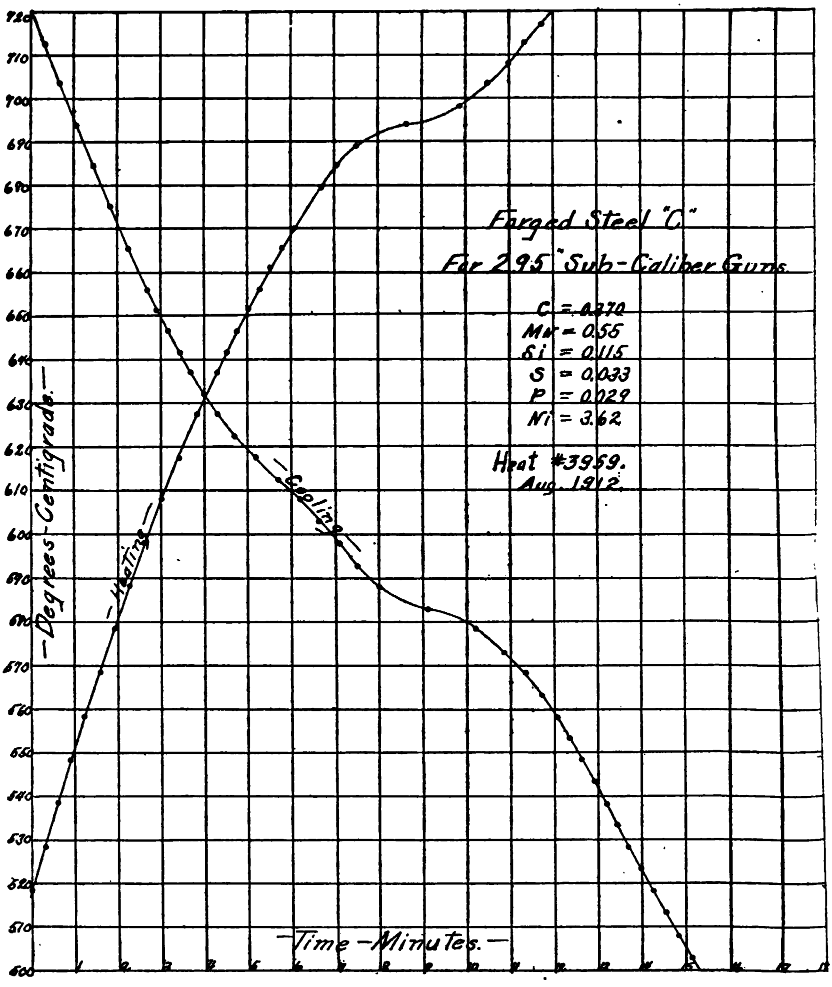
11
12
13
14
15
16
17
18


770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
—Degrees—Centigrade—
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
—Time—Minutes—
Heating
Cooling
FORGED STEEL "B"
Heating & Cooling Curves.
C = 0.434
Mn. = 0.290
Si = 0.176
S = 0.021
P = 0.021
Ni = 3.100


Forged Steel "C"
For 2.95" Sub-Caliber Guns.
C = 0.370
Mn = 0.55
Si = 0.115
S = 0.033
P = 0.029
Ni = 3.62
Heat #3959.
Aug. 1912.
—Heating—
—Cooling—
—Degrees-Centigrade.—
—Time-Minutes.—
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
1
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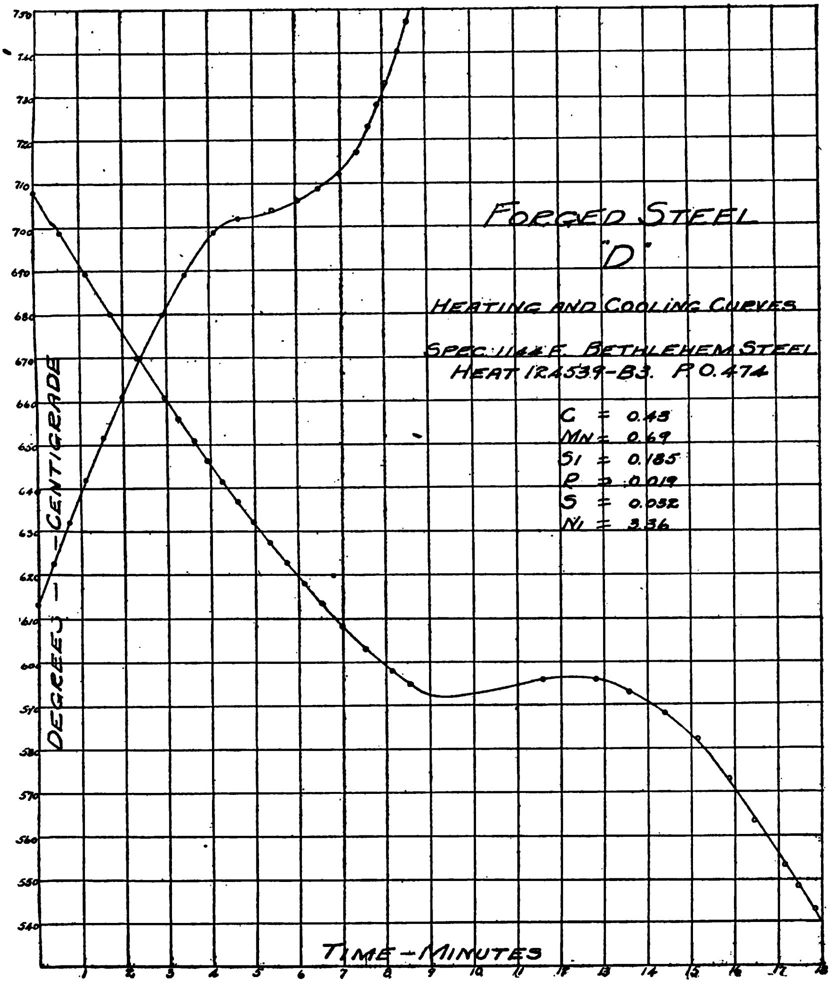
FORGED STEEL
"D"
HEATING AND COOLING CURVES
SPEC. 1144 E. BETHLEHEM STEEL
HEAT 124539-B3. P.O. 474
C = 0.43
MN = 0.69
SI = 0.185
P = 0.019
S = 0.032
NI = 3.36
DEGREES — CENTIGRADE
TIME — MINUTES
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540
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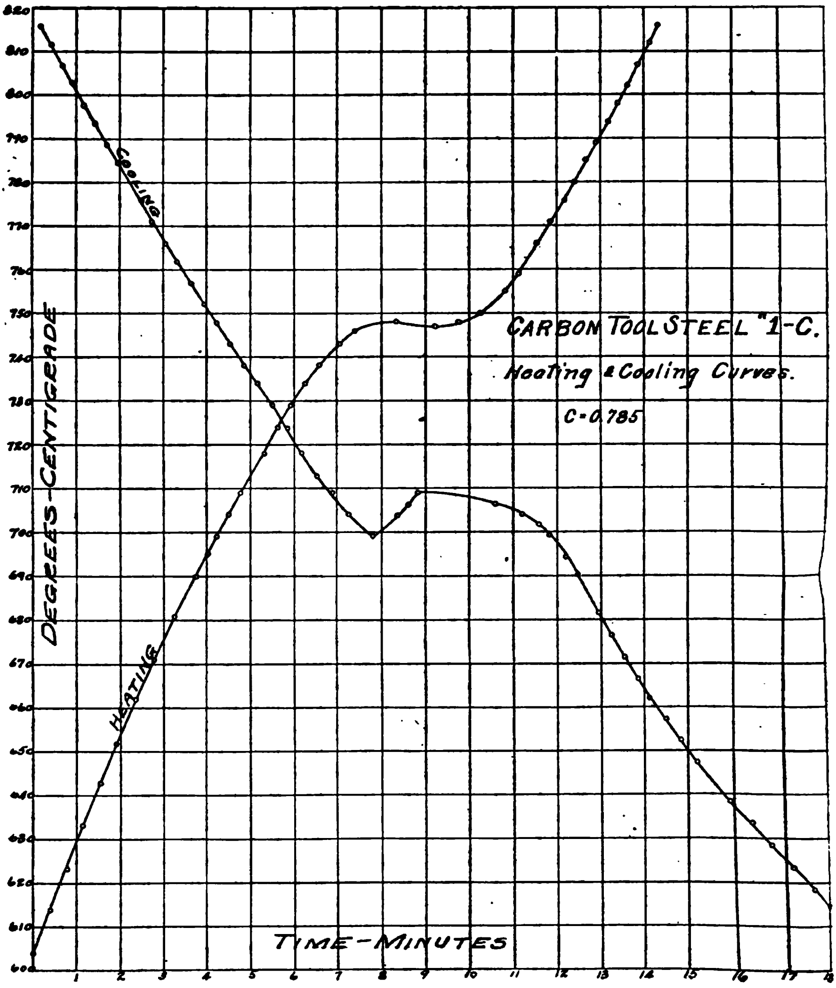
CARBON TOOL STEEL "1-C.
Heating & Cooling Curves.
C=0.785
COOLING
HEATING
DEGREES-CENTIGRADE
TIME-MINUTES
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
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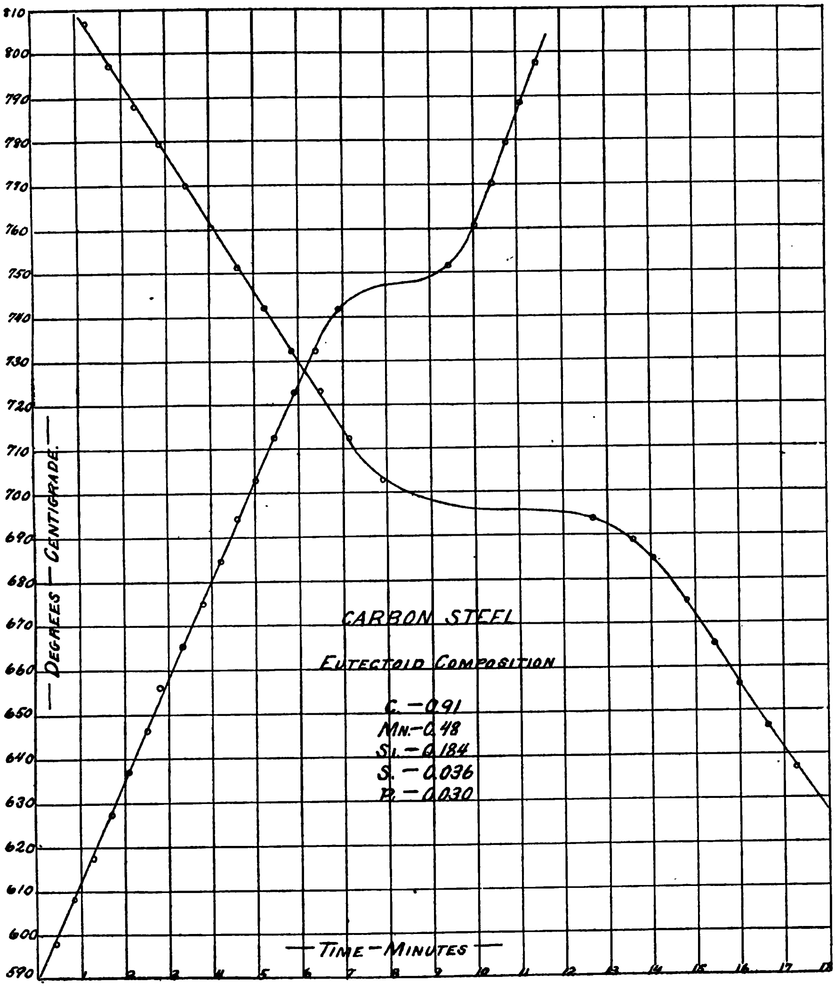
CARBON STEEL
EUTECTOID COMPOSITION
C.—0.91
MN.—0.48
SI.—0.184
S.—0.036
P.—0.030
— DEGREES — CENTIGRADE.
— TIME — MINUTES —
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
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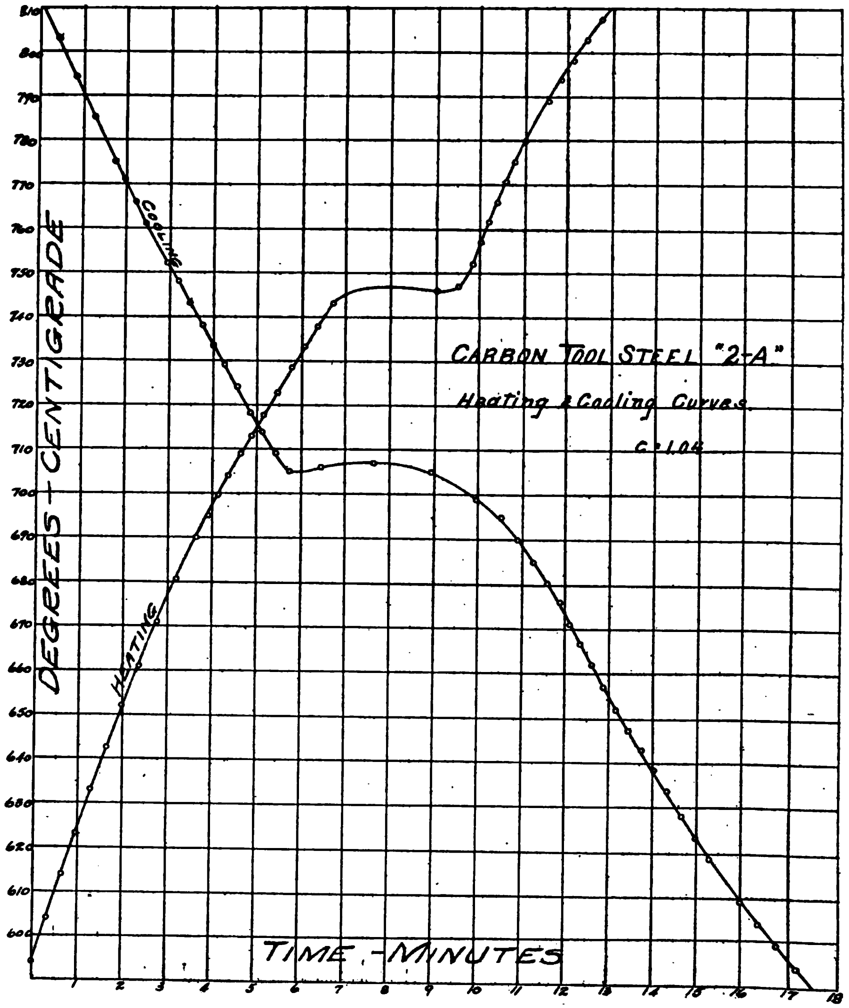
CARBON TOOL STEEL "2-A"
Heating & Cooling Curves
C=1.04
COOLING
HEATING
DEGREES - CENTIGRADE
TIME - MINUTES
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
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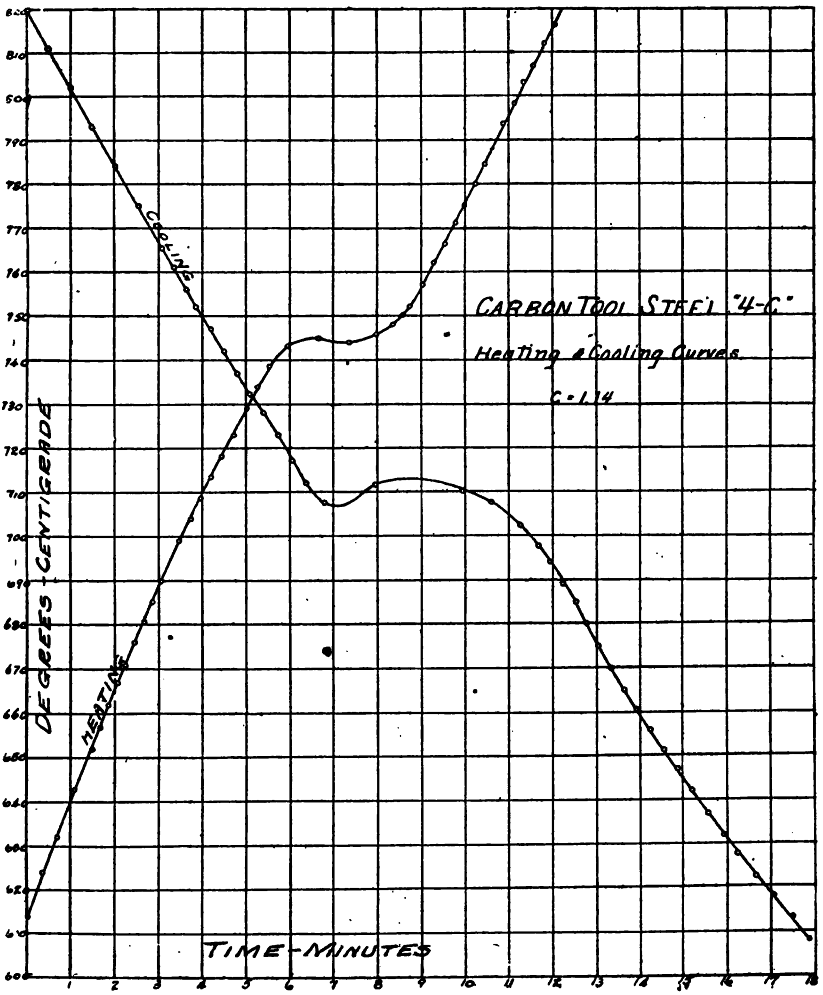
CARBON TOOL STEEL "4-C"
Heating & Cooling Curves.
C = 1.14
COOLING
HEATING
DEGREES - CENTIGRADE
TIME - MINUTES
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
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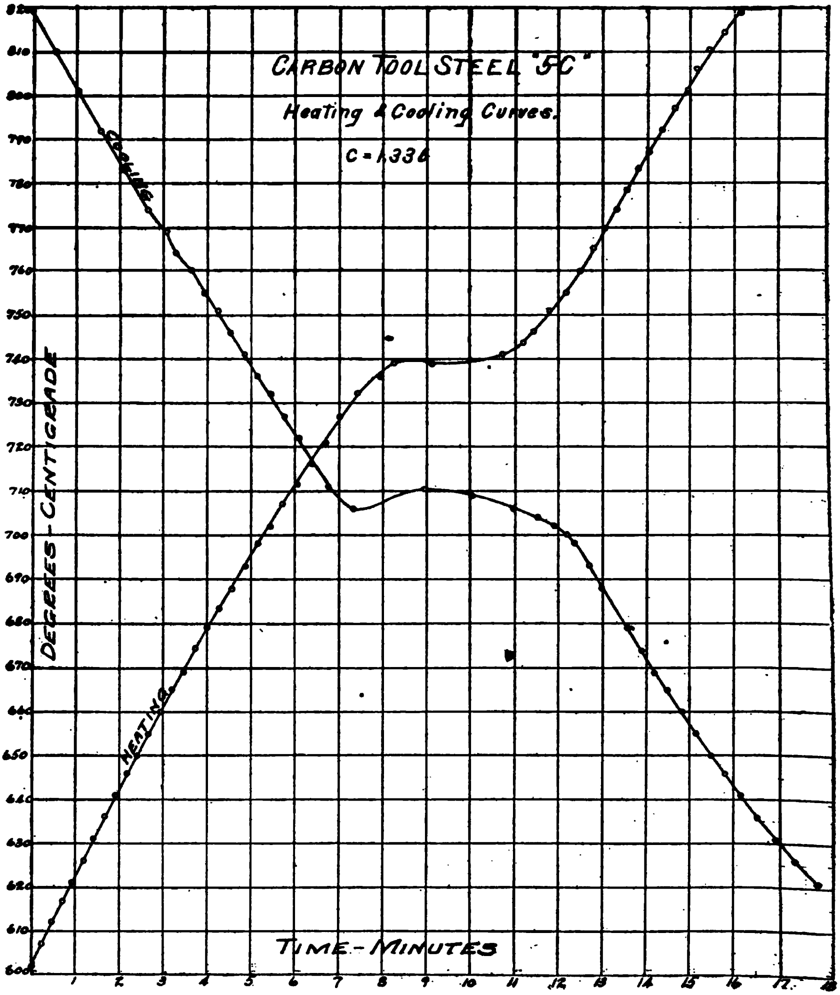
CARBON TOOL STEEL "5C"
Heating & Cooling Curves.
C = 1.336
Cooling
Heating
DEGREES - CENTIGRADE
TIME - MINUTES
820
810
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
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METALLOGRAPHIC EXAMINATIONS.

METALLOGRAPHIC EXAMINATIONS.

EXAMINATION OF BRONZES, SHOWING VARIOUS SIZES OF GRAIN.

Bronze No.	Test piece.		Approximate chemical composition.					Tensile strength.	Elongation.	Contraction.
	No.	Description.	Copper.	Zinc.	Tin.	Steel alloy.	Aluminum.			
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Per ct.*	*Per ct.*
3	1109	Very coarse..	57	42.5	0.5	....	....	58,400	11	11.6
4	1187	Coarse.......	58.54	38.7	....	2.55	0.21	69,200	13	16.3
4	1185	Fine........	58.54	38.7	....	2.55	.21	61,000	36.5	33.8
3	1194	Oxidized....	57	42.5	.5	....	....	45,000	10.5	9.3

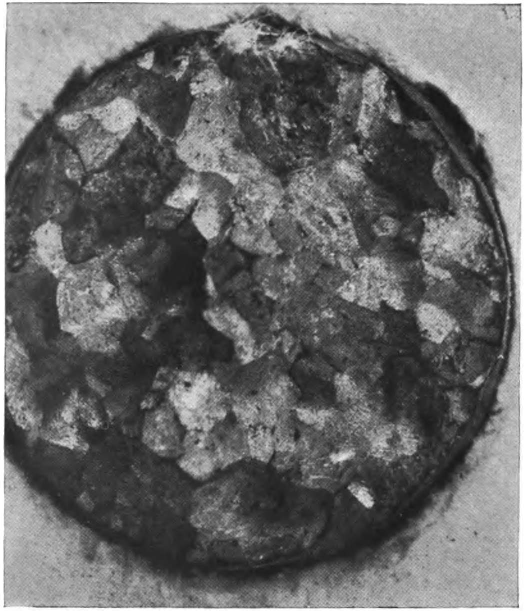
The above-reported bronzes were regular Watertown Arsenal bronze test specimens which came to the laboratory for routine testing. The data on them have been collected and are presented herewith as being of interest because of the great difference in the fractures.

Test specimen No. 1109 shows an extraordinarily coarse fracture with very large and distinct crystals. This bronze also shows very low ductility as measured by elongation and contraction. Such a coarse fracture as this tends to indicate that the metal was poured much too hot, or possibly too cold. The fracture is clean, however, and does not indicate excessive oxidation.

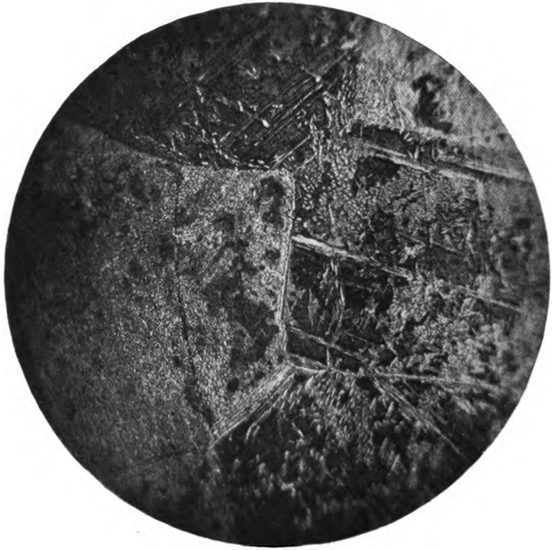
Test specimen No. 1187, of Watertown Arsenal No. 4 bronze, shows the same type of fracture as No. 1109, though not nearly so coarse. The crystals are quite distinct and indicate that this bronze also was poured either too hot or too cold. The strength of this specimen was good, but the ductility was low.

Test specimen No. 1185 is very good all around. The strength is but slightly under that of No. 1187, and the ductility is materially bettered. The fracture shows a fine grain and the microstructure is characteristic of a good bronze.

Test specimen No. 1194 shows low ductility on account of oxidation of the metal. This oxidation is readily seen in the photograph of the fracture.

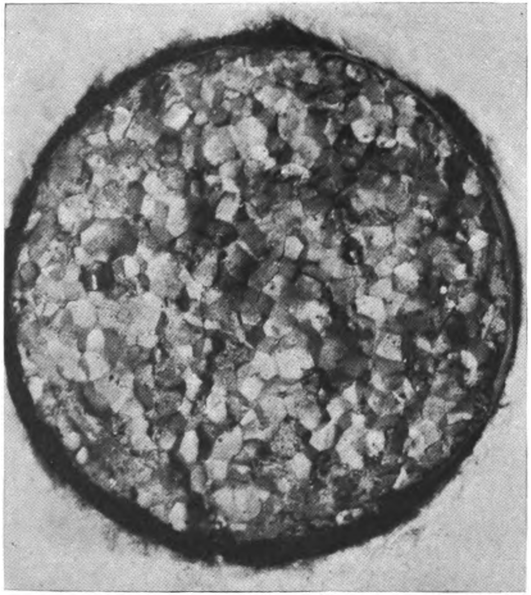


NO. 1109. FRACTURE. (3½X.)

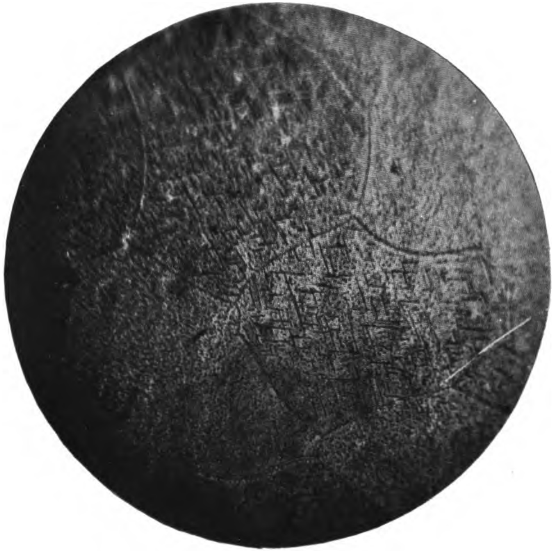


NO. 1109. (MICROGRAPH 20X.)

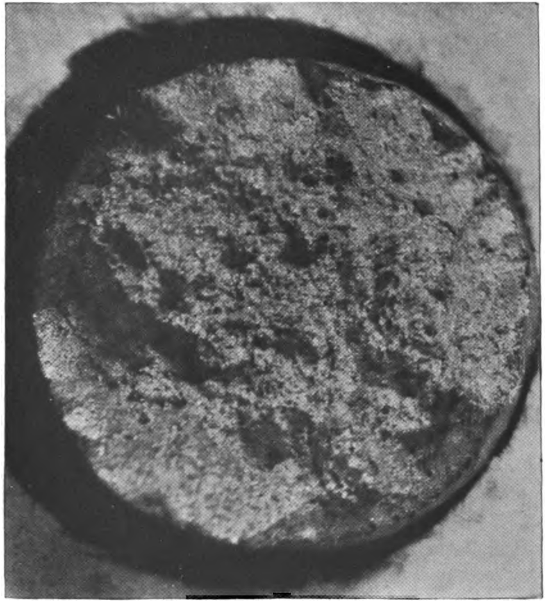
204-2



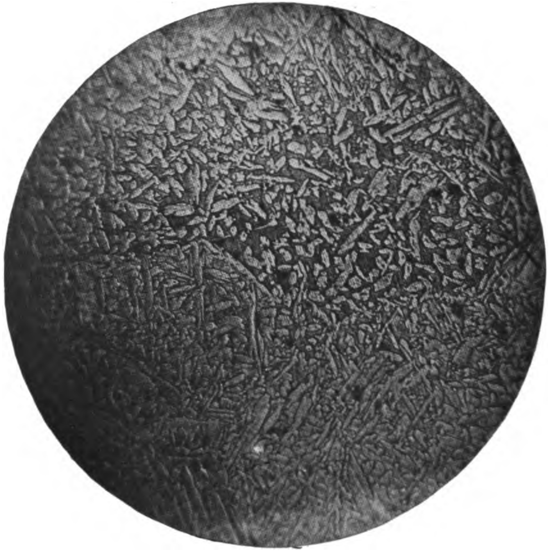
NO. 1187. FRACTURE. (4X.)



NO. 1187. (MICROGRAPH 20X.)

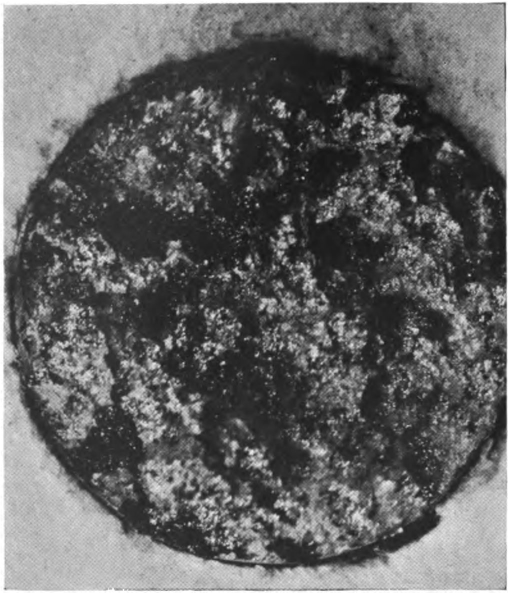


NO. 1185. FRACTURE. (4X.)

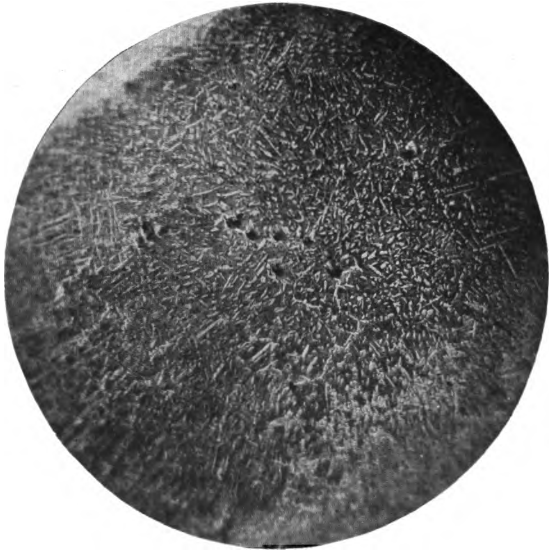


NO. 1185. (MICROGRAPH 20X.)

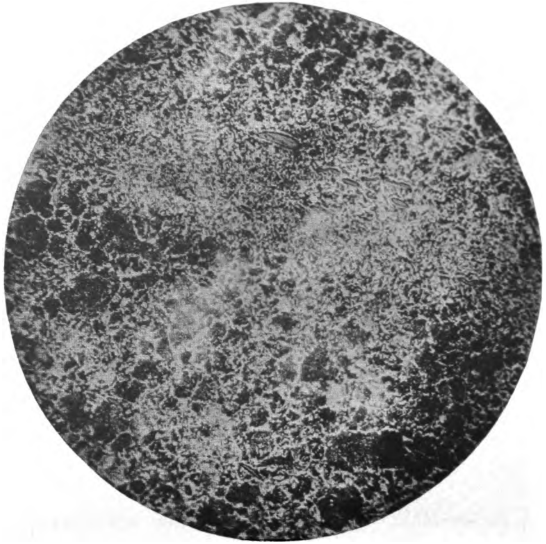
204-4



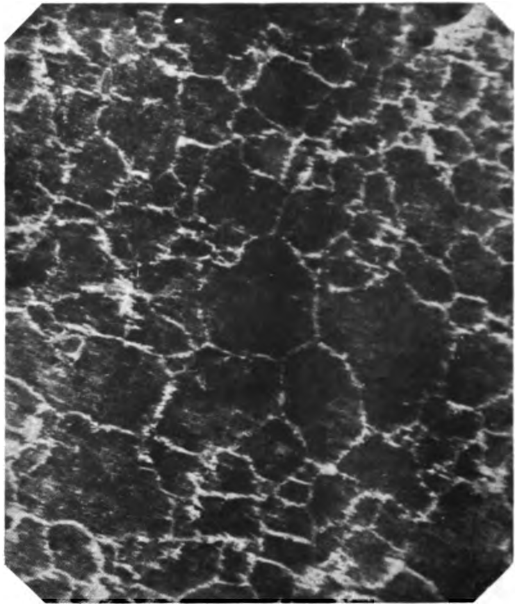
NO. 1194. FRACTURE. (3½X.)



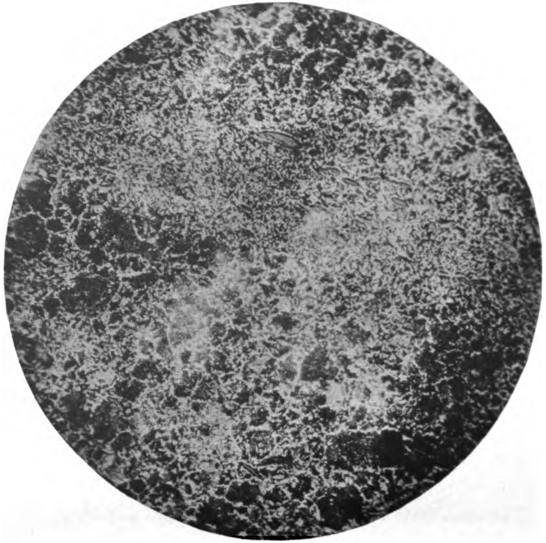
NO. 1194. (MICROGRAPH 20X.)



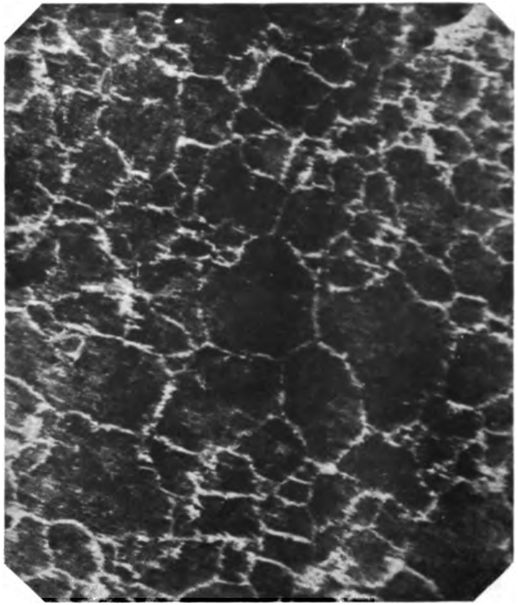
PHOTOGRAPH NO. 1. 12-INCH MORTAR JACKET, NO. 128758 B1. SHOWS SLAG AND A WELL-DEVELOPED STREAK IN WHICH STRUCTURE IS DIFFERENT FROM THE MATERIAL OUTSIDE OF STREAK. (X50.)



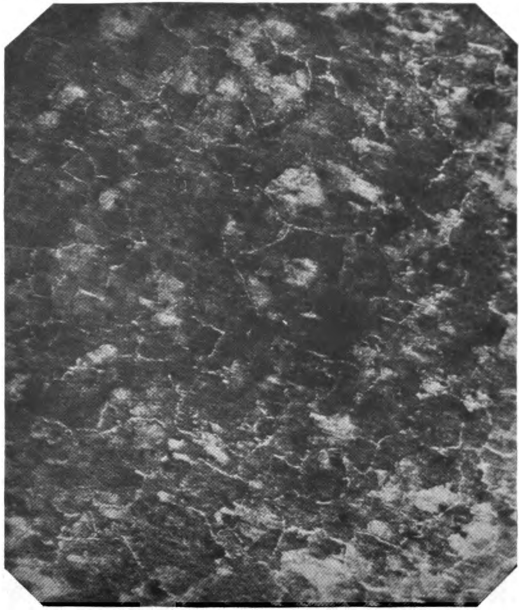
PHOTOGRAPH NO. 2. SPECIMEN B. T. 3 L, GUN NO. 128840 B2. (X75.)



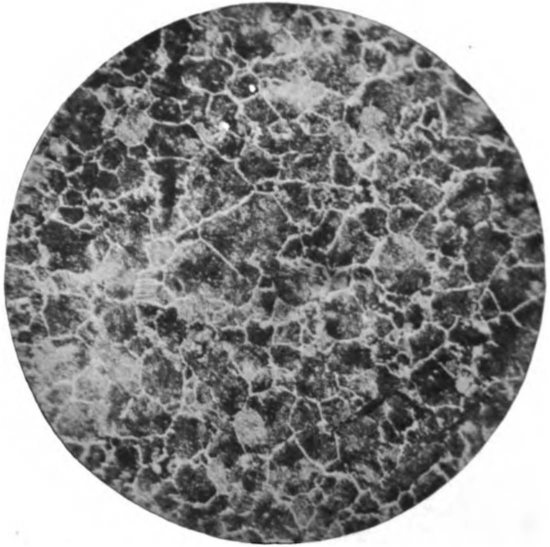
PHOTOGRAPH NO. 1. 12-INCH MORTAR JACKET, NO. 128758 B1. SHOWS SLAG AND A WELL-DEVELOPED STREAK IN WHICH STRUCTURE IS DIFFERENT FROM THE MATERIAL OUTSIDE OF STREAK. (X50.)



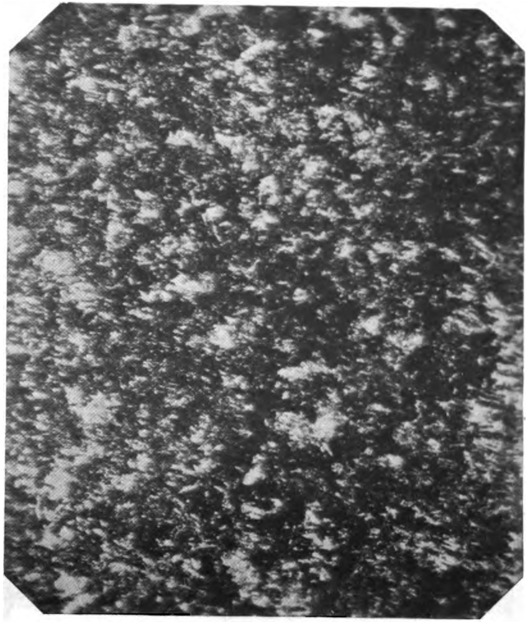
PHOTOGRAPH NO. 2. SPECIMEN B. T. 3 L, GUN NO. 128840 B2. (X75.)



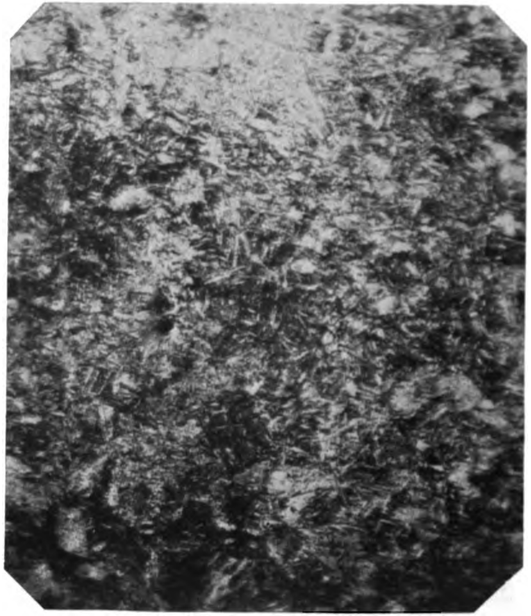
PHOTOGRAPH NO. 3. GUN NO. 128799 B2, B. T. 2 M. (X 75.)



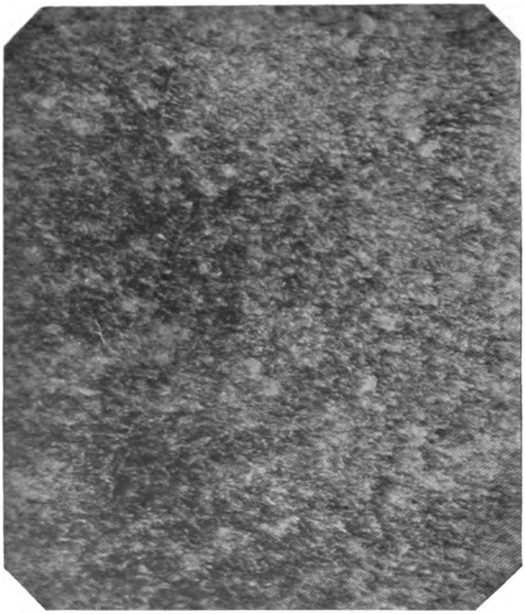
PHOTOGRAPH NO. 4. VERY CHARACTERISTIC GRAIN DEVELOPMENT WITH CELL WALLS OF FERRITE. GUN NO. 128738 B1. (X50.)



PHOTOGRAPH NO. 5. GUN L 703, OUTER. (X75.)



PHOTOGRAPH NO. 6. GUN L 703, MIDDLE. (X75.)



PHOTOGRAPH NO. 7. GUN L 703, INNER. (X75.)

205-4

MICROSCOPIC EXAMINATION OF TEST SPECIMENS OF GUN FORGINGS.

The object of this series of examinations was to obtain information regarding the character of the heat treatment of gun steels, and to get data as to the possibility of incorporating into the existing specifications a clause relating to the type of microstructure.

Inasmuch as the number of specimens was very large, it was decided to select at random various specimens. In some cases portions of all test pieces submitted from a particular gun were examined, and in other cases random specimens illustrating successful and unsuccessful physical tests were examined.

Each specimen was examined in the polished but unetched condition for slag, and after etching for 10 seconds with 4 per cent alcoholic nitric acid for type of structure.

Slag was found in a surprisingly large number of specimens, but mostly in a fine state of subdivision and consequently in a form which would not show its effects appreciably on the physical properties. It was present in such quantities in some specimens, however, as to produce on the etched specimen very well-marked and good-sized streaks. In such cases the slag was drawn out in the direction of forging and occupied the central portion of the streaked area. A very good example of this was found in 12-inch mortar jacket 128758 B1, as shown in photograph No. 1.

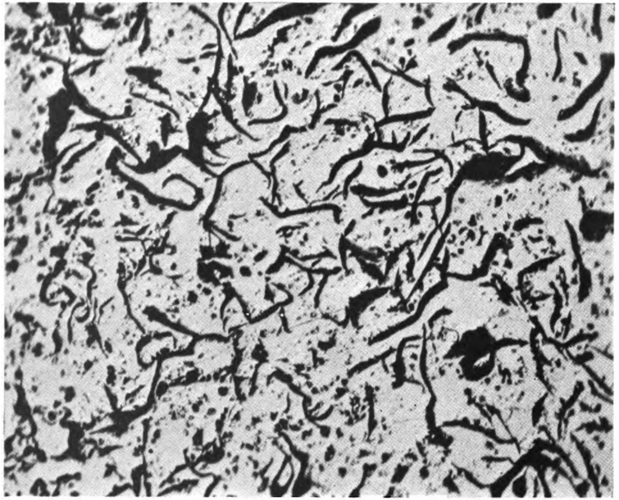
The structure usually found was sorbitic in character and indicated a satisfactory heat treatment. There were variations from this, however, which were important. The most satisfactory structure shows a uniform field with even distribution of the ferrite and cementite, and both in a very fine state of subdivision with little or no tendency for ferrite to form cell walls. In some cases this cell wall or granular formation was very marked, as shown in photographs Nos. 2, 3, and 4, taken from guns indicated. This is probably not a dangerous structure to have, but it does not seem so desirable as the more homogeneous structure without the cell formation.

Another variation of importance is found in specimens taken from the test pieces representing the inner, middle, and outer sections of gun L703. The middle portion is quite different from the inner and outer portions, and these in turn are slightly different from each other. The middle portion shows a semimartensitic structure which indicates that the oil-hardened material had not been sufficiently drawn so as to convert it into the sorbitic condition. The outer section shows a troostitic structure which is a transition between that of martensite and sorbite. Photographs Nos. 5, 6, and 7 show the structure of the outer, middle, and inner test pieces taken from the muzzle end of gun L703. Not only do variations of this kind occur in the inner, outer, and middle sections of the breech or muzzle ends of the forging, but there are variations between the muzzle and breech ends of the same forging.

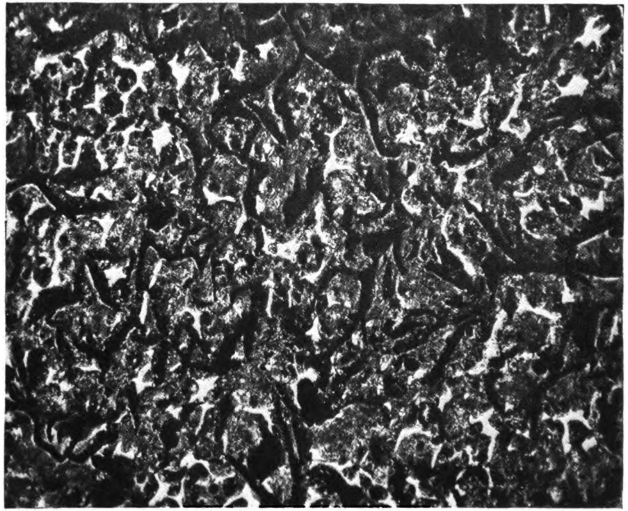
It was not thought desirable to examine all of the test pieces submitted, as it was fully believed similar variations would be found. It is not known to what extent the presence of slag and streaks and the variations of structure such as found would have upon the life of a gun, but it seems highly desirable to have as little foreign material as possible present, and it is fully believed that a more uniform type of structure should be found in all guns. Having once decided by experimental evidence upon the most desirable type of structure, this type could then be reproduced in each gun. The exact reproduction would be complicated somewhat by the size of the forging, but means could be devised to overcome this difficulty.

METALLOGRAPHIC EXAMINATIONS.

CHEMICAL AND MICROSCOPICAL EXAMINATION OF CAST-IRON SHELL.



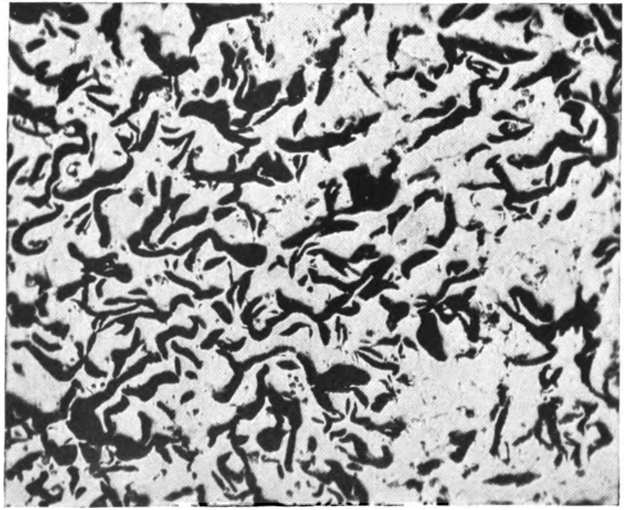
NO. 2. UNETCHED. (X75.)



NO. 2. ETCHED. (X75.)

T. C	3.335
G. C	2.180
C. C	1.155
Mn	.54
Si	1.672
S	.218
P	.667
Tensile strength ... pounds	33,900

206-2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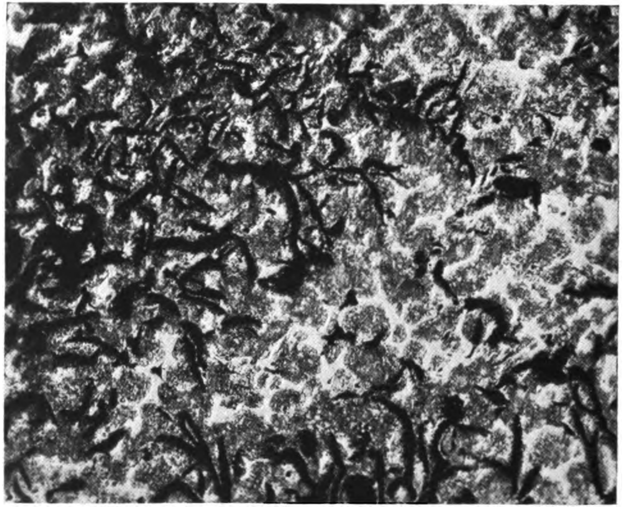
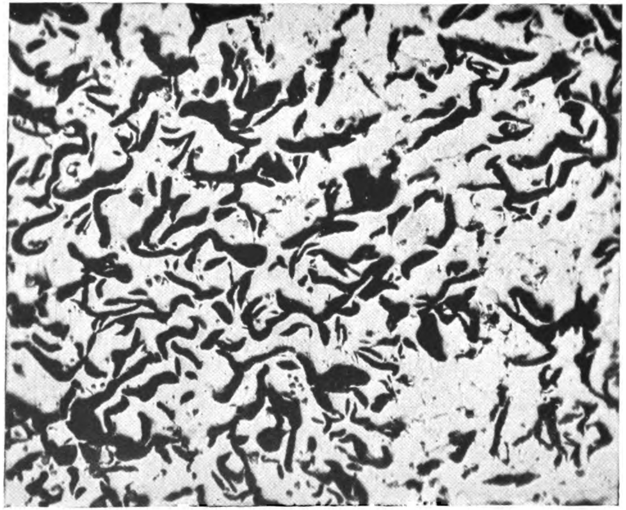

NO. 3. ETCHED. (X75.)

T. C	3.346
G. C	2.045
C. C	1.305
Mn	.45
Si	1.460
S	.240
P	.678
Tensile strength . . . pounds	33,800



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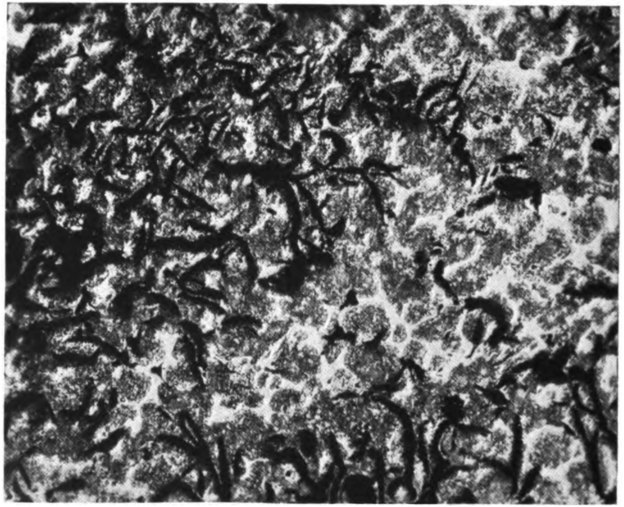
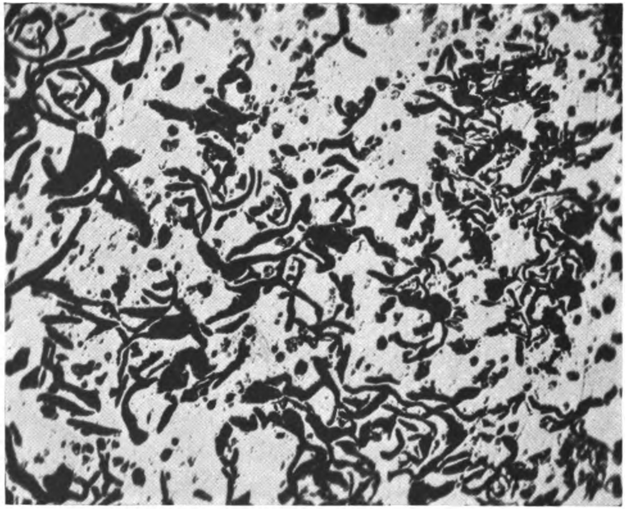


NO. 3. ETCHED. (X75.)

T. C	3.346
G. C	2.045
C. C	1.305
Mn	.45
Si	1.460
S	.240
P	.678
Tensile strength ... pounds	33,800



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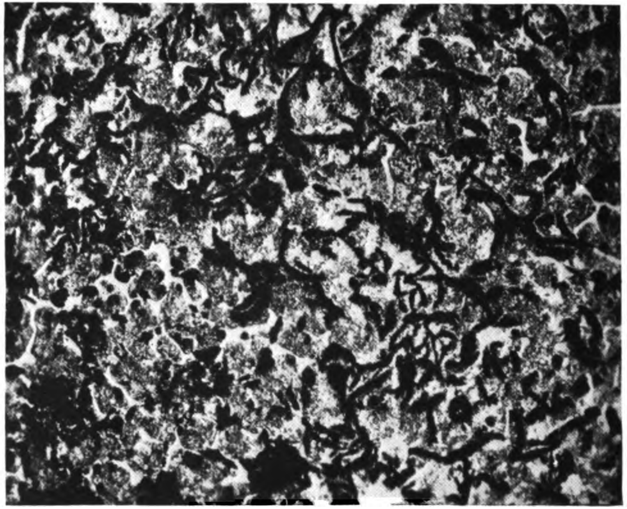
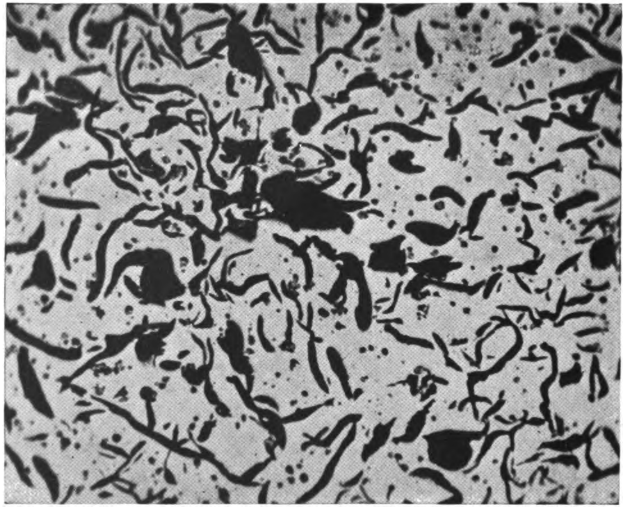


NO. 4. ETCHED. (×75.)

T. C	3.390
G. C	2.462
C. C	.928
Mn	.41
Si	1.432
S	.215
P	.614
Tensile strength ... pounds	32,950



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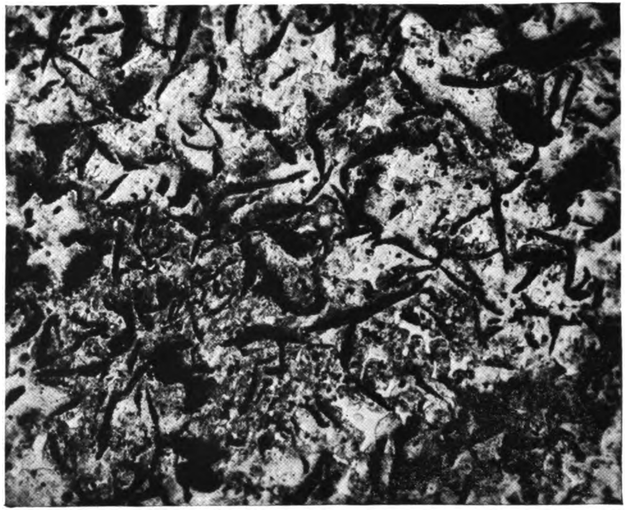
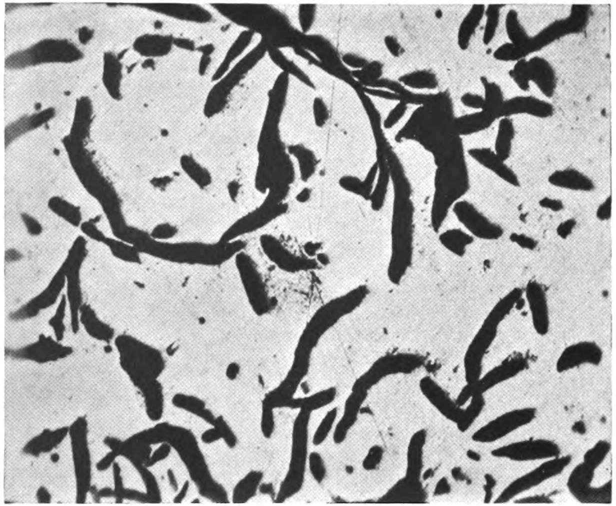


NO. 6. ETCHED. (X75.)

T. C		3.526
G. C		2.432
C. C		1.094
Mn		.66
Si		1.565
S		.227
P		.715
Tensile strength	pounds	31,950



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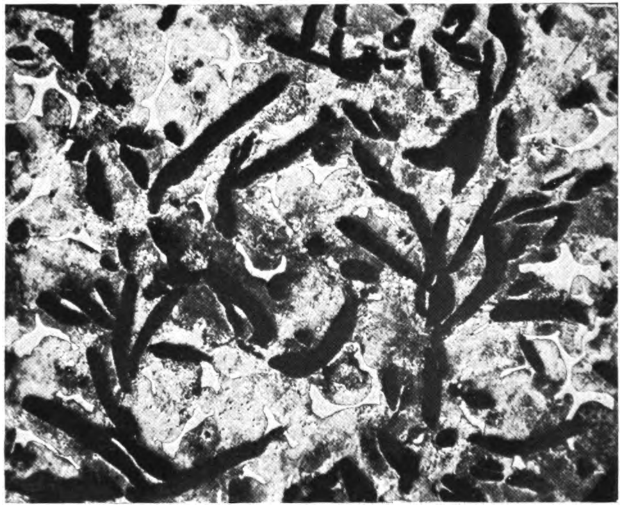
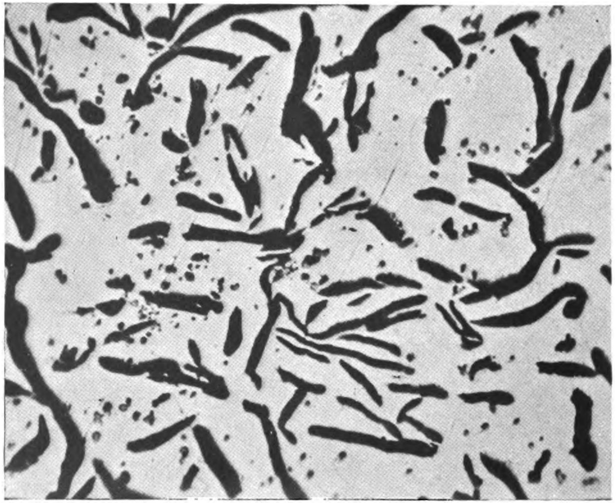


NO. 20. ETCHED. (X75.)

T. C		3.028
G. C		2.364
C. C		.664
Mn		.52
Si		1.386
S		.165
P		.565
Tensile strength	pounds	33,150



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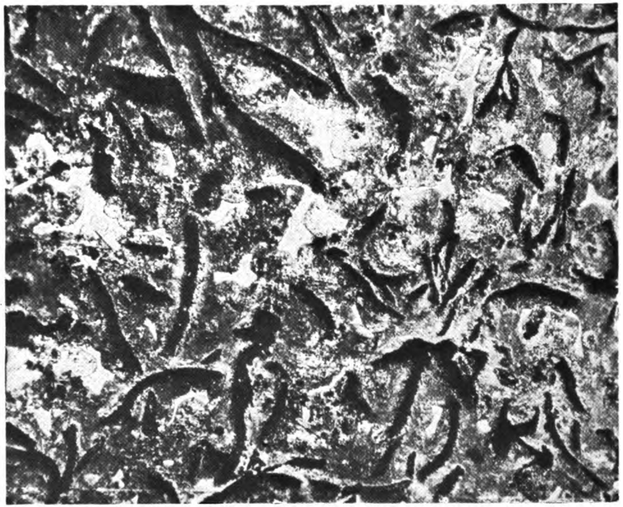

NO. 22. ETCHED. (X75.)

T. C		3.185
G. C		2.440
C. C		.745
Mn		.60
Si		1.542
S		.198
P		.690
Tensile strength	pounds	33,000

EROSION OF GUNS.

EROSION OF GUNS.

Since the report upon "tests of trepanned rings from 12-inch guns," which appeared in the Tests of Metals for 1913, further evidence has been obtained on the cause of the formation of the hard surface layer in guns. This evidence has been developed through a further study of specimens taken from the trepanned 12-inch gun and from some tests made on pressure plugs. Through experiments made upon some experimental pressure plugs considerable additional and important evidence has been obtained.

It is generally believed that heat cracks are the result of the unequal expansion which takes place between the hard and soft layers of metal; the harder layer, being the more brittle, relieves the tension in the form of cracks. It is important, therefore, to consider the cause of the hard layer.

(A) Hardening may be produced by raising the temperature of the steel above the Ac_1 point and cooling it very quickly through the Ar_1 point.

(B) Hardening may be produced by cementation of the surface at high temperature and pressure by the products of combustion of the powder.

(C) Hardening may be produced by mechanical work done upon the metal by means of the rotating band.

1. (A) In producing hardness by this method it is necessary to assume that the surface of the metal is heated to at least 730° C. and is very quickly cooled by the surrounding large mass of metal. The temperature of the explosion chamber is much higher than is necessary to produce this result, and it is highly probable that the temperature throughout the gun is sufficiently high to raise a skin of the metal above its Ac_1 point.

If this method of hardening is the cause of the hard surface layer, a cross section of the layer should show a martensitic structure and perhaps the transition structure of troostite between the martensite and the normal sorbitic structure of the gun. Rosenhain[1] and also Belaiew[2] have reported martensite in the hardened surface of the rifling of a gun, but so far in the various guns examined no distinct martensitic structure has been found, although evidences of troostite have been found. This would indicate strongly that the hard layer was produced by this process, although the microscopic evidence is not conclusive. It is difficult to see, however, why selective action should take place on the driving edges of the muzzle end of the gun if this process alone were acting. Light on this phenomena is furnished by examination of the experimental pressure plugs, which will receive consideration after discussing the other methods of producing hardness.

2. (B) The products of combustion of the powder charge are carbon monoxide, carbon dioxide, water vapor, and nitrogen, and there is

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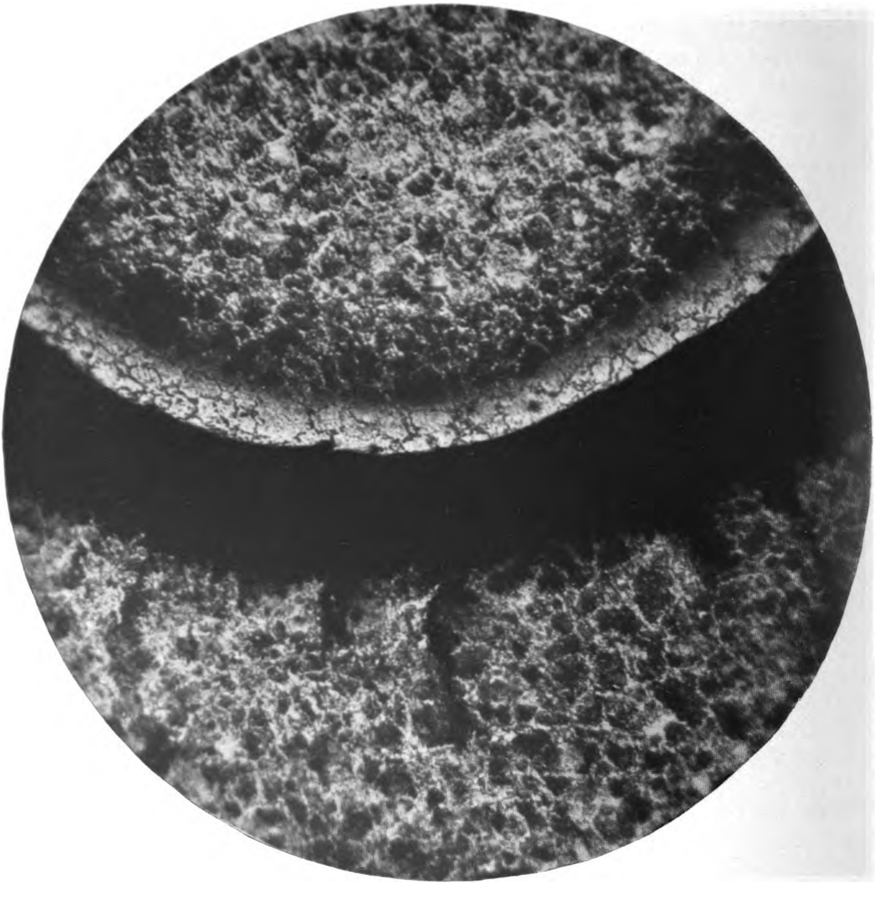
[1] Rosenhain: Discussion Int. Soc. Testing Materials, 1913, Section A, p. 122.

[2] Belaiew: Discussion Int. Soc. Testing Materials, 1913, Section A, p. 122.



PHOTOGRAPH NO. 1 (X75.)

abundant evidence from many sources, but none more convincing than the recent work of Giolitti and Carnevali,[1] that steel may be carbonized by carbon monoxide under pressure. By this process the surface may be enriched in carbon, and iron carbide or cementite, a very hard, brittle material, is produced. Such a process may easily go on in the combustion chamber and some distance forward, but it is difficult to see why selective action in favor of the driving edge should take place. Cementite, the microscopic constituent, is distinguished by the fact that it etches to a dark color when heated in a solution of sodium picrate. Experiments with this reagent have given negative results, and while this process of producing hardness may be a contributory cause, it is certain that it is not the main cause, otherwise evidences of cementite would have been found.

3. (C) The recent work of Beilby[2] has thrown much light upon the nature of surface hardness produced by friction. He has shown that when a surface of any metal is subjected to friction the surface layer flows in much the same manner as if in the liquid condition. This skin of metal shows unmistakable evidence of its having possessed the mobility of a liquid, and in its final state is hard and amorphous, and is easily distinguished from the metal immediately beneath it.

In the firing of a gun there is abundant opportunity for the production of a hardened skin of this type, due to the friction between the rotating band and the rifling. The greatest amount of friction should be produced in the early stages of the explosion when the projectile is beginning to attain its velocity and when the rotating band is in contact with the whole surface of the rifling. The friction should, however, be diminished toward the muzzle end on account of the wearing away of the rotating band. This theory would account satisfactorily for the fact that at the muzzle end of the gun there is found a hardened skin only on the driving edge of the land. It will not, however, account for the fact that the pressure plugs also show a hardened surface.

In order to study the effect of firing upon pressure plugs, two experimental plugs were prepared for service and careful chemical analysis and microscopic examination was made of the steel before placing in service. After having been in service for some time they were returned for further examination, with the following results:

It was hoped to make a chemical analysis for carbon of the hardened surface, but the hardening had been selective in its action, and this, therefore, was not feasible.

Careful microscopic examination brought out the fact that hardening had taken place selectively, and that the places where the action had occurred corresponded to points where pressure or work upon the metal had been severe. It seemed, therefore, that there was some relationship between the growth of the hard surface and the amount of work put upon the metal. This is well illustrated in photograph No. 1, which shows a portion of the letter O. The die, in making its impression upon the metal, compressed the interior of the letter from all sides and consequently to a greater extent than the exterior. The hard material appeared uniformly on the edge of the interior, while it had only begun to form on the exterior. In the formation of the letter S similar results were obtained, with the maximum amount of hardness in the interior of the two bands. Another example is shown in photograph No. 2, which shows a period stamped in the metal. On one side only is shown the formation of the hard material. This might be accounted for by assuming that the die had not been held in a truly vertical position, and that one side had received somewhat more work than the other, and at that side the formation of the hard surface had taken place. Other evidence of similar character was obtained from nearly every letter on the face of the pressure plug, not only from the stamping of the letters but from the machining of the material.

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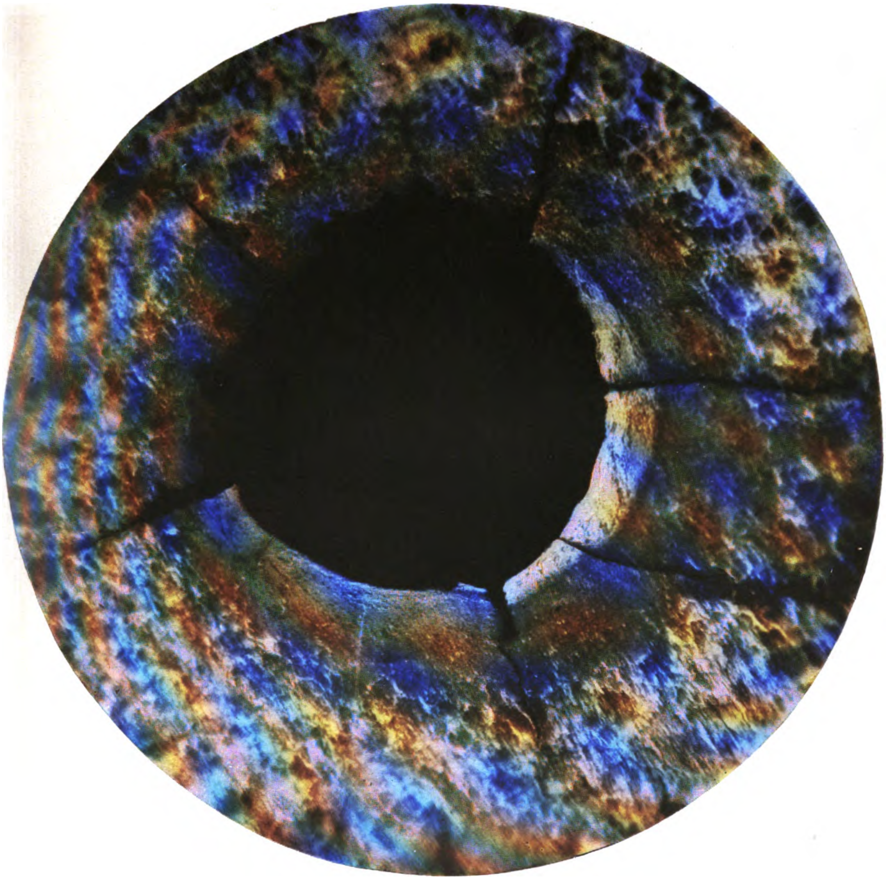
[1] Giolitti and Carnevali: Journ. Iron & Steel Institute, 1911, No. 2, p. 331.
[2] Beilby: Inst. of Metals, Vol. VI, p. 5.

Cementation, as the chief cause of hardness, must be eliminated because of the failure to get any reaction with sodium-picrate solution. It became evident from the pressure-plug experiments that the growth of hard metal is in some way connected with the plastic deformation produced, either by the rotating band upon the rifling or the work of the die in stamping the letters on the pressure plug. In other words, the strained metal is apparently more sensitive or reactive than the same material in the unstrained condition. Considering methods A and C of hardening as working together, there seems to be a reasonable explanation for all of the phenomena observed in the interior of guns.

This view would necessitate the presence of martensite in these hard surfaces, and so far it has not actually been observed, but indirect evidence speaks in its favor. On tempering metal containing the hard material, troostite, a transition form between martensite and sorbite has been found, and this could result by the method employed only from martensite. Further, troostite has been observed adjacent to the hard layer, and also in the positions where the hard layer is in process of formation. When it is considered that in all positions where hardness occurs there is also plastic deformation, it is not surprising that the normal needlelike structure of martensite is missing.

The evidence presented herewith is in no sense to be considered conclusive, but merely as a step toward the solution of the problem. Further experiments are in progress with the hope of throwing more light on this question.



PHOTOGRAPH NO. 2., (X75.)

PRIVATE TESTS.

PRIVATE TESTS.

Tests made for private parties during the fiscal year ended June 30, 1914.

Date.	Material.	Name.	City and State.
1913.			
July 18	Eyebolts	New England Bolt & Steel Co.	Everett, Mass.
21	Concrete building block.	Gustave Rappoli	Medford, Mass.
21	.....do	S. D. Lake	Winchester, Mass.
22	Rope	Columbian Rope Co.	Auburn, N. Y.
24	Rubber belting	Boston Woven Hose & Rubber Co.	Boston, Mass.
30	Iron bars	Laconia Car Co.	Laconia, N. H.
Aug. 8	Concrete building block.	S. R. Shultz	Buffalo, N. Y.
9	.....do	Gustave Rappoli	Medford, Mass.
9	Buoy shackles	Fletcher & Crowell	Portland, Me.
18	Concrete building blocks.	J. Pacanowski	Buffalo, N. Y.
20	Chain	Fletcher & Crowell	Portland, Me.
20	Shackles and swivels	.....do	Do.
25	Concrete building blocks.	Gustave Rappoli	Medford, Mass.
26	.....do	.....do	Do.
28	Automobile hinges	Soss Manufacturing Co	Boston, Mass.
29	.....do	.....do	Do.
Sept. 2	Concrete building blocks.	Ralph Sylvester	Medford, Mass.
5	Steel from shaft	Rumford Falls Power Co	Rumford, Me.
6	.....do	.....do	Do.
9	Iron bar	Laconia Car Co.	Laconia, N. H.
12	Wire rings	Hood Rubber Co.	Watertown, Mass.
13	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
16	Columns with screw caps	United States Column Co.	Cambridge, Mass.
19	Rope	Columbian Rope Co.	Auburn, N. Y.
25	White metal	Sauveur & Boylston	Cambridge, Mass.
30	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
Oct. 1	Interlocking tiles	The Ohio Clay Co.	Cleveland, Ohio.
9	Turnbuckles	Marine Hardware Equipment Co.	South Portland, Me.
10	Concrete building blocks.	City of Lawrence	Lawrence, Mass.
22	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
Nov. 3	Steel	Savage Arms Co.	Utica, N. Y.
12	Rubber belting	Revere Rubber Co.	Chelsea, Mass.
17	Snatch and gun blocks	Boston & Lockport Block Co.	East Boston, Mass.
24	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
25	Steel	Savage Arms Co.	Utica, N. Y.
26	Cast iron	Turners Falls Co.	Turners Falls, Mass.
29	.....do	Davis & Farnum Mfg. Co.	Waltham, Mass.
29	Chrome vanadium steel.	Leonard Waldo	New York, N. Y.
Dec. 6	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
8	Concrete building blocks.	Columbia Concrete Co.	West Somerville, Mass.
8	.....do	The Dry Wall Block Co. (Inc.)	Buffalo, N. Y.
8	Steel plates and roller	Herbert E. Dickson	New York, N. Y.
13	Building bricks	New England Brick Co.	Boston, Mass.
16	Steel	Savage Arms Co.	Utica, N. Y.
18	Concrete building blocks.	Wm. J. McCarthy Co.	Somerville, Mass.
19	.....do	H. S. Hemingway	Do.
29	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
30	Babbitt	Sauveur & Boylston	Cambridge, Mass.
31	.....do	.....do	Do.
1914.			
Jan. 6	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
13	Steel	Savage Arms Co.	Utica, N. Y.
14	Iron bars	Laconia Car Co.	Laconia, N. H.
16	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
19	Iron bars	James F. Marley	Boston, Mass.
20	Swivel hook	Boston & Lockport Block Co.	East Boston, Mass.
26	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
28	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
29	Concrete building blocks.	The Star Concrete Co.	Buffalo, N. Y.
30	Steel	Prof. Albert Sauveur	Cambridge, Mass.
Feb. 2	.....do	Savage Arms Co.	Utica, N. Y.
3	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
7	Cast-iron brackets	United States Column Co.	Cambridge, Mass.
13	Cast iron	Barbour & Stockwell	Do.
14	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
16	Steel	Savage Arms Co.	Utica, N. Y.
17	Cast iron	Davis & Farnum Mfg. Co.	Waltham, Mass.
26	Buoy shackles	Fletcher & Crowell	Portland, Me.

Tests made for private parties during the fiscal year ended June 30, 1914—Continued.

Date.		Material.	Name.	City and State.
1914.				
Mar.	4	Granite cubes	Stone Mountain Granite Co	Stone Mountain, Ga.
	5	Links	Marine Hardware & Equipment Co.	South Portland, Me.
	6	Cast iron	Barbour & Stockwell	Cambridge, Mass.
	10	Concrete building blocks.	The Dry Wall Block Co. (Inc.)	Buffalo, N. Y.
	14	Iron bars	The Laconia Car Co	Laconia, N. H.
	16	Steel	Savage Arms Co	Utica, N. Y.
	24	Concrete brick and concrete building blocks.	The Bridgeport Stone Co	Bridgeport, Conn.
	25	Concrete slab	The Berger Mfg. Co	Boston, Mass.
	30	Steel	Savage Arms Co	Utica, N. Y.
Apr.	6	Iron bars	Laconia Car Co	Laconia, N. H.
	8	.....do	Sauveur & Boylston	Cambridge, Mass.
	9	Bronze	Hudson Metals Co. (Inc.)	Bayonne, N. J.
	9	Steel	Standard Steel Works	Philadelphia, Pa.
	13	Steel tubing	The Henry Souther Engineering Co.	Hartford, Conn.
	15	Concrete building blocks.	W. E. Harrington	Boston, Mass.
	15	Iron brackets	United States Column Co	Cambridge, Mass.
	16	Shelf supports	The Snead & Co. Iron Works	Jersey City, N. J.
	17	.....do	.....do	Do.
	17	Stucco block	John W. Duff	Boston, Mass.
	25	.....do	Trussed Concrete Steel Co	Do.
May	1	Iron bars	Laconia Car Co	Laconia, N. H.
	2	Babbitt	Sauveur & Boylston	Cambridge, Mass.
	4	Column	United States Column Co	Do.
	6	Buoy shackles	Fletcher & Crowell	Portland, Me.
	8	Concrete building blocks.	J. F. Dwyer	Medford, Mass.
	8	.....do	The Bridgeport Stone Co	Bridgeport, Conn.
	9	.....do	Wiedrick & Menders	Buffalo, N. Y.
	13	Steel	Savage Arms Co	Utica, N. Y.
	13	Conduits	H-B Construction Co. (Inc.)	Buffalo, N. Y.
	18	Cast iron	Davis & Farnum Mfg. Co	Waltham, Mass.
	19	.....do	Laconia Car Co	Laconia, N. H.
	22	Steel	H. B. Layman	New York, N. Y.
	27	Manila rope	Arlington Mills	Lawrence, Mass.
June	2	Concrete building blocks.	Albert E. Atkinson	Buffalo, N. Y.
	2	.....do	H. S. Hemingway	Somerville, Mass.
	8	Cast iron	Laconia Car Co	Laconia, N. H.

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